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Economic Impact Analysis of Proposed Section 5 Notice Requirements. Appendix: Volume II

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16. ABSTRACT

This report presents the analysis of the economic impact of TSCA section 5 rules on the chemical industry. The industry will be impacted when it introduces new chemicals. Of the six distinguishable consequences for the chemical industry, the most important are the nonquantifiable uncertainty consequences. The more unclear EPA's rationale in making section 5 notice decisions, the greater are the uncertainties.

There will likely be a short-run drop in the number of new chemicals introduced into commerce as chemical companies shift their innovation activities into "safe" chemicals. Current data do not allow a quantitative estimate to be made of the rate of chemical introductions, or the extent of the reduction caused by the section 5 notice requirements; and, even if the data were available, it is doubtful that accurate quantitative predictions could be made.

Smaller companies will face greater uncertainties and the direct costs will more often be a factor in company decisions. In the long run, this regulation may cause the chemical industry to be composed of a fewer number of larger competitors better able to absorb the direct costs and regulatory uncertainty associated with the requirements.

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ECONOMIC IMPACT ANALYSIS OF PROPOSED SECTION 5 NOTICE REQUIREMENTS

APPENDIX: VOLUME II

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APPENDIX E

CHEMICAL SEGMENT PROFILES

INTRODUCTION

ICF Incorporated (ICF) has developed the following profiles of chemical industry segments as part of its continuing work in analyzing the impact on the chemical industry of the premanufacturing notice provisions of the Toxic Substances Control Act (TSCA). These profiles were undertaken for three reasons. First, they provided ICF with the opportunity to survey all segments of the chemical industry that would be affected by the provisions so that the structure, conduct, and performance of these industry segments could be tentatively and crudely assessed. Second, they provided ICF with a mechanism for narrowing the in-depth portion of the work to segments in which significant amounts of innovation will probably occur. Finally, they insured that ICF would seek only that data from the industry which was not available in the public file and was necessary to complete the economic analysis of this set of regulations. (Industry would be least burdened in supplying data for this analysis.)

These profiles are organized into seven segments: inorganic chemicals; synthetic high polymers; amphipathic compounds; elementary organics; organics, not elsewhere classified; catalysts; and other chemical products. Within each segment, component product profiles are provided. For those segments which contain more than one component product profile the first page of the chapter lists the component product summary and then provides a brief description of the segment's general characteristics.

These profiles are based on publicly available data only. Major sources of information are: Census of Manufactures, Kline Guide to the Chemical Industry, 10-Ks and annual reports, trade journals, and business periodicals. Within each profile sources are clearly noted.

Readers of these profiles will note that the length of the profiles varies substantially. This reflects ICF's efforts to focus resources. For example, if a component product had extremely small sales volume, was characterized by no innovation, and was not likely to be affected by innovation in other component products, ICF dismissed it. For sectors in which substantial innovation is occurring (according to public sources), considerable effort was devoted to insure that public data on this segment have been exhaustively explored.

In addition to the principal authors of this report, the following individuals contributed substantially to this appendix: Aaron Goldberg, Lori Hashizume, Glenn Kautt, Kenneth Kolsky, Frank Lerman, Steven Payson, Steven Stern, and Marguerity Voorhees.

On the next page we list the component products and segments in the order in which they occur in this document.

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INORGANIC CHEMICALS

Inorganic Chemicals Segment Summary

Industrial Gases

Fertilizers

Inorganic Pigments

All Other Inorganic Chemicals

Inorganic Chemicals are chemicals that are not carbon-based. As a result, they have relatively limited bonding ability and usually cannot be used as building blocks to form large molecules. This factor acts to lower their structural and functional diversity.

In general, there appears to be relatively little product innovation in the inorganic chemicals segment. The difficulty in forming large molecules, referred to above, is one reason for this lack of innovation. Another reason is that the study of inorganic chemicals is one of the oldest fields in chemistry. Because of the relative lack of product innovation in inorganic chemicals, inorganic chemicals markets typically exhibit the following features:

- Many important products have the status of commodity chemicals - standardized products produced on a very large scale.
- Commodity chemicals tend to be produced by large companies, and the markets are often highly concentrated. Because of the importance of commodity chemicals in the inorganic chemicals segment, market concentration is higher in inorganics than in other segments of the chemical industry.
- There is a great premium on process innovation in commodity chemicals, and in inorganic chemicals in general. Even though producers find it difficult to capture new markets through the introduction of new products, by improving the efficiency of their production processes manufacturers may be able to lower costs, lower prices, and capture new markets.
- Research and development expenditures tend to be concentrated in engineering process innovations rather than in basic scientific research.

The above description should not lead one to believe that there is no innovation in the inorganic chemical segment. In recent years certain new boron phosphate and silicon compounds have been developed, and some firms have been working with rare earth salts, though the latter has, as yet, been produced in amounts too small for commercial development. In addition, process innovation often leads to the development of new chemical intermediates.

It may be a mistake to predict that future innovation in inorganic chemicals will look like past innovation. In recent years an enhanced theoretical understanding of inorganic chemistry has emerged from university laboratories. These theoretical innovations have not yet been translated into commercial innovations, but it is quite possible that they may be commercialized in the future. If so, innovation in the inorganic chemical segment could increase substantially.

E-4

Industrial Gases

INDUSTRIAL GASES

DESCRIPTION

The industrial gases are comprised of nine gases, many of which have been used by the chemical industry for over 100 years.[1] The largest dollar volume industrial gas is oxygen, which in 1977 accounted for 37 percent of total dollar shipments. Following oxygen, ranked by dollar volume of shipments, are nitrogen, acetylene, carbon dioxide, and hydrogen. Helium and argon rank sixth and seventh, respectively, in dollar volume sales for 1978.[2]

Generally, industrial gases are produced in one- or two-step processes, and are themselves later used as feedstocks for the production of other chemicals. They may be in solid, liquid, or gaseous form; transportation and handling considerations often determine the physical state of the industrial gases. Transportation through pipelines is becoming an increasingly popular method, in which case the gaseous state is desirable. For transportation in cylinders, tank cars, or barges, the liquid or--less often--the solid state is used.

ENGINEERING PROCESS

Industrial gases are obtained from three main sources: the air, hydrocarbons, and the processing of other chemicals and elements--such as calcium carbide--which yield these gases as byproducts or coproducts. The first source, the air, requires the least complex processing. Air is liquefied at extremely low temperatures and its components are separated, producing hydrogen, oxygen, nitrogen, and smaller amounts of argon and other elements which are present in traces.

Hydrocarbon processing, the second method of obtaining industrial gases, involves treating natural gas. Argon and helium are frequently obtained in this fashion.

Additionally, much of the industrial gas produced is obtained as a byproduct or a coproduct of other chemical operations. The gas is drawn off and purified, to be used later. If the industrial gas production, treatment, and use are done in one plant or in adjacent facilities, the production is known as "captive". Data on captive production and consumption are usually not included in commerce reports, and it is estimated that overall production data for industrial gases is, therefore, about 15 percent too low.[3]

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[1] All industrial gases are contained in the SIC category 2813.

[2] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, N.J.: Charles Kline & Co., 1977).

[3] Chemical Purchasing, October 1977.

USES

Industrial gases are used primarily in the chemical, metals, and food industries (see Table 1 and Figure 1). They are also used diversely in manufacturing and are increasingly important in petroleum recovery.

The chemical industry utilizes industrial gases extensively in the formulation of intermediate and final products. Acetylene, for example, is an important building block in the production of vinyl chloride and a number of various plastic products. Hydrogen is used in numerous steps of petroleum refining. The production of fertilizer also requires large quantities of industrial gas.

The metals industry uses some industrial gases to control the degree to which metals will or will not react. Oxygen, for example, finds its primary use in the steel industry, where its highly reactive nature increases the temperature and efficiency of furnace operations. Argon and helium, on the other hand, are extremely inert; they are used when a protective, non-reactive atmosphere is needed. Argon is used extensively in welding operations.

The food industry utilizes industrial gases for refrigeration and freezing. Nitrogen, hydrogen, and carbon dioxide are liquefied at very low temperatures and then circulated, cooling or freezing the areas around them. The freeze-drying of foods, as well as the freezing of prepared foods, is a huge and fast-growing use. Carbon dioxide is also used extensively in the production of soft drinks.

Other applications for industrial gases include the atmosphere within electric light bulbs and tubes (argon and neon), and anaesthetics (nitrous oxide). Additionally, energy research has indicated huge potential for the use of industrial gases in energy storage and transmission, as well as in fusion and conventional fission reactions.

The petroleum industry is using increasing amounts of industrial gas, particularly carbon dioxide, for oil well stimulation. The gas is either applied alone or combined with water to pressurize wells and aid secondary and tertiary oil recovery. Higher prices for oil should stimulate increased utilization of carbon dioxide for oil stimulation and should encourage the shipment of merchant carbon dioxide into oil fields.4/

INDUSTRY STRUCTURE

The industrial gas industry is extremely concentrated. While there are numerous production locations, only a limited number of large companies

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4/ *Ibid*.

TABLE 1

MAIN USES OF INDUSTRIAL GASES

Metals	Food	Chemicals	Other
Oxygen	Carbon Dioxide	Acetylene	Argon
Argon	Nitrogen	Nitrogen	Helium
Helium		Hydrogen	Hydrogen
Nitrogen		Argon	Neon
			Nitrous Oxide

FIGURE 1

CONSUMPTION PATTERNS

ACETYLENE

vinyl chloride	(24.6%)
welding & metal cutting	(20.7%)
acrylates & acrylic acid	(20.7%)
vinyl acetate	(14.4%)
acetylenic acid	(6.9%)
tetrahydrofuran	(6.7%)
other	(6.0%)

CARBON DIOXIDE

Capitive Use	(44%)
chemical raw material for urea production	(40%)
chemical raw material for production of methanol and sodium carbonate; inerting; pressurizing in coal mining; and oil recovery	(4%)
Merchant Use	(56%)
oil well stimulation	(30%)
refrigeration	(11%)
carbonation	(5%)
chemical raw material	(3%)
inerting	(3%)
pressurizing	(1%)
miscellaneous applications	(3%)

FIGURE 1 (Continued)

CONSUMPTION PATTERNS

CARBON DIOXIDE (cont'd.)		
	Steelmaking	(50.6%)
	basic oxygen process	(39.6%)
	open hearth	(9.3%)
	electric furnace	(1.7%)
	Other Steel Industry Applications	(14.8%)
OXYGEN	Non-Ferrous Metal Industry	(12.0%)
	Chemicals	(12.0%)
	ethylene oxide	(4.9%)
	acetylene	(2.3%)
	titanium dioxide	(1.7%)
	propylene oxide	(1.4%)
	vinyl acetate	(1.4%)
	miscellaneous chemicals	(0.3%)
	Miscellaneous Applications	(10.6%)

Source: Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed., Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977).

consistently supply the market, and only a small number have large national sales. In 1976, combined sales of the three largest producers accounted for 65 percent of total shipments. Sales of the six largest accounted for 91 percent of the total[5] (see Table 2). It should be noted that because the concentration ratio is based on the value of shipments, rather than on production figures, industrial gases produced captively are not reflected. Thus, there are actually many more sizeable producers than the concentration ratio would indicate.

Part of the reason for both the large number of captive producers and the extremely high concentration ratio is the economics of transportation involved for industrial gases. With the exception of pipeline transport, general shipment of industrial gases further than approximately 200 miles is not feasible.[6] This constraint results in a substantial number of smaller regional producers, an incentive for captive production and consumption, and a small number of very large volume producers who have access to a pipeline and can thereby transport large volumes of gas over long distances.

PRICES

Pricing trends for industrial gases have not been consistent. Measured in constant dollars, the prices of most industrial gases fell quite steadily from 1967 to 1973 (see Table 3). In 1974, however, a significant price increase occurred. A general trend of increasing prices has since continued up through 1978.

Just as the pricing past was somewhat unstable, the pricing future is uncertain as well. The biggest threat to prices is the potential for overcapacity and overproduction.[7] It is not clear if demand for industrial gases will increase substantially in the next few years, as some predictions claim, if it will grow only moderately or if overcapacity will be realized and prices will drop.

In addition to overall supply, the major factor affecting industrial gas prices is the sharply rising cost of energy. The production of industrial gases is extremely energy-intensive, regardless of which engineering process is used. Thus, any industrial gas price must reflect the cost of this important production factor.

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[5] Meegan, Kline Guide.

[6] Chemical Purchasing, October 1977.

[7] Ibid.

TABLE 2

MAJOR U.S. PRODUCERS OF INDUSTRIAL GASES: 1976

Rank	Company	$ Million
1	Union Carbide	$ 325
2	Airco	220
3	Air Products & Chemicals	190
4	Chemetron	95
4	Houston Natural Gas	95
4	Big Three Industries	95
	Other	105
	Total	$1,125[a]

[a] U.S. Department of Commerce figure of 984 is approximately 15 percent too low, as it does not include the complete value of the conversion of liquid gas.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles Kline and Company, 1977).

TABLE 3

INDEX OF AVERAGE MANUFACTURERS' PRICES OF INDUSTRIAL GASES: 1967-1976

Year	O_2, High Purity	Nitrogen, High Purity	Acetylene	CO_2	Hydrogen	Argon, High Purity	Total[a]
1967	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1968	99.7	100.5	102.4	90.8	94.7	117.5	99.5
1969	91.5	92.5	98.6	77.0	105.9	111.5	94.7
1970	91.9	84.1	104.0	74.0	119.5	107.0	92.3
1971	89.0	76.8	124.7	64.8	128.4	71.8	87.4
1972	75.9	68.0	122.2	66.1	119.4	64.1	75.8
1973	73.3	68.4	146.2	62.5	142.6	60.6	72.1
1974	83.8	73.9	195.1	73.4	180.6	75.7	87.0
1975	108.5	94.5	292.5	77.9	181.5	109.4	108.3
1976	101.3	88.6	284.7	84.4	172.6	101.6	103.8

[a] Excludes CO_2

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 84.

TABLE 4

INDUSTRIAL GAS PRODUCTION: 1973-1977

Industrial Gas	Production Unit	1977	1976	1975	1974	1973
Acetylene[a]	Mil. cu. ft.	5,972	7,111	6,704	7,808	8,269
Carbon Dioxide	Short tons	2,255,814	2,063,665	1,850,318	1,804,251	1,565,506
Argon, High Purity	Mil. cu. ft.	5,925	5,107	4,457	4,688	4,325
Helium[b]	Mil. cu. ft.	N/A	1,339	1,078	883	3,205
Hydrogen[c]	Mil cu. ft.	84,506	82,100	73,552	81,536	65,169
Nitrogen[d], [e]	Mil. cu. ft.	331,545	288,868	252,368	243,316	227,160
Oxygen[d], [e]	Mil. cu. ft.	392,984	388,446	352,554	389,628	389,436
Nitrous Oxide	1,000 gals (STP)	N/A	1,940,969	1,652,298	1,628,271	1,281,590

[a] Excludes information from railroad ships, shipyards, welding shops, and small establishments using portable generators.

[b] U.S. Department of the Interior, Bureau of Mines.

[c] Excludes amounts vented, used as fuel, etc., and amounts produced and consumed in the manufacture of synthetic ammonia and methanol, but includes an unspecified amount produced for sale or interplant transfer to plants consuming this gas in the production of ammonia. Also excludes amounts produced by the ammonia dissociation process. Also excludes amounts produced in petroleum refineries for captive use.

[d] Excludes amounts produced and consumed in the manufacture of synthetic ammonia or ammonia derivatives.

[e] Data for 1973 and 1972 include figures for high and lower purity gas.

SOURCE: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports (Washington, D.C.: Government Printing Office, 1977).

INNOVATION

Most industrial gases have been used for over a century, and the industry is generally considered to be quite mature. There have been no major product or process innovations for a number of years, and none are expected. There have been, however, a number of important use innovations in the past few years, and there is a definite potential for further innovations of this type.

The most important recent use innovation involves the use of argon in the production of stainless steel. Discovered in 1968 by Union Carbide and Joslyn Stainless Steel, this process substantially increases the quality of stainless steel and is becoming increasingly popular with manufacturers. It is estimated that currently more than 90 percent of U.S. stainless steel is manufactured by the argon-oxygen decarburization process.8/

A number of use innovations appear to have already been discovered or hypothesized by researchers, but have not yet been put into practice. We feel that this has occurred for one of two reasons: either the use innovation has not yet been refined to a degree sufficient to allow widespread acceptance and use, or it is not yet cost effective. The extent to which these potential uses are put into practice may determine pricing trends and patterns for industrial gases in the coming years.

An example of use innovation with a huge potential that has not yet been exploited is helium. Among its potential uses are magnetic containment systems for fusion reactors; high temperature gas turbines; laser-based missile defense systems; magnetic propulsion units for new transport systems; and low-temperature energy transmission, distribution, and storage.9/ Additionally, hydrogen may be used to store energy for motor vehicles and stationary power plants,10/ oxygen may be used in the treatment of wastewater by revitalizing aerobic bacteria, and nitrogen has begun to replace natural gas as an inert blanketing agent for metals, electronics, and chemical processing.11/

8/Chemical & Engineering News, August 21, 1978.

9/Science, December 7, 1979, p. 1145.

10/Chemical & Engineering News, May 15, 1978.

11/Chemical & Engineering News, July 16, 1979.

FOREIGN TRADE

There are virtually no imports of industrial gases. Exports, however, have generally been increasing over the past years. Nitrogen is an exception to this trend; its exports fell by nearly $244 million between 1976 and 1977. Overall, during the period 1973-1977, the value of industrial gas exports increased from $6,441,000 to $20,838,000, or by 224 percent (see Tables 5, 6).

SHIPMENTS

Total shipments of industrial gases were $1,080 million in 1977 compared to only $572 million in 1967.[12] Constant dollar shipment forecasts are approximately $1,300 million in 1980 and $1,850 million in 1985.

The substantial increase in the dollar volume of foreign trade and shipments is related to both volume and price. Price increases (Table 3) have been large for a number of industrial gases--particularly acetylene and hydrogen. Although acetylene production fell from 8,269 million cubic feet in 1967 to 7,111 million cubic feet in 1976, the value of production was 67 percent higher in 1976.

Hydrogen experienced both price and production increases, such that the adjusted value of production was 52 percent higher in 1977 than in 1973.

For some industrial gases, particularly nitrogen and carbon dioxide, volume increases have been the important factor in the increased value of shipments. From 1973 to 1977, production of nitrogen increased by 46 percent, and production of carbon dioxide increased by 44 percent.

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[12] Meegan, Kline Guide, p. 81

TABLE 5

U.S. EXPORTS--DOLLAR VALUE OF SHIPMENTS

SIC	Commodity	Unit of Shipment	1973	1974	1975	1976	1977
281320 00	acetylene	MCF	62,637	261,926	273,941	264,577	569,644
281330 00	carbon dioxide, nitrous oxide, & carbon monoxide	--	1,040,447	1,131,152	1,526,283	1,866,551	2,156,015
281340 20	oxygen[a]	MCF	670,266	720,028	1,682,422	2,098,415	2,467,005
281340 40	nitrogen[b]	MCF	1,074,719	1,220,582	1,448,891	2,310,414	2,066,481
281340 97	hydrogen, rare gases, & liquid air	MCF	3,592,820	5,232,779	7,761,984	10,733,842	13,398,819

[a] Changed to 281360 00 in 1977 figures.

[b] Changed to 281350 00 in 1977 figures.

Source: U.S. Department of Commerce, U.S. Exports, FT 610, various years.

TABLE 6

BALANCE OF TRADE: INDUSTRIAL GASES
(thousands of dollars)

	1977	1976	1975	1974	1973	1965
Value of Exports	20,838	17,274	12,694	8,566	6,441	3,164
Value of Imports	--	--	--	--	--	--
Balance of Trade	20,838	17,274	12,694	8,566	6,441	3,164

Source: Totals from Table 5.

FERTILIZERS

FERTILIZERS

DESCRIPTION

Until recently, natural organics such as manure, wood ash and bone meal were used to supply nutrients necessary for plant growth. Most of these materials have since been replaced by chemical fertilizers. The first chemical fertilizer, superphosphate, was developed in the early 19th century, and physical mixing of several fertilizer materials occurred in 1849. By the early 1930s, scientists discovered ways to chemically combine multinutrient fertilizers--ammoniating superphosphate was the first attempt at this.

Fertilizers are mainly composed of the primary nutrients needed for plant growth: nitrogen, phosphorus, and potassium. SIC codes 2873 and 2874 encompass the nitrogenous and phosphatic fertilizer industries, respectively. Potassium compounds fall under SIC code 2819, and mixing fertilizers are covered by SIC code 2875. For purposes of our analysis we exclude industry 2875 because items in this category are not chemicals per se, but products like compost, mixed fertilizers, and potting soil.

ENGINEERING PROCESS

Ammonia is the starting point for almost all nitrogen fertilizers. Ammonium nitrate, for example, is derived by the action of ammonia vapor on nitric acid. Ammonium sulfate, also a nitrogenous fertilizer, is derived by one of several processes: 1) reaction with sulfuric acid, followed by crystallization and drying, 2) neutralizing synthetic ammonia with sulfuric acid, 3) as a byproduct of caprolactum (a chemical used to manufacture synthetic fibers and plastics), and 4) from gypsum, by reaction with ammonia and carbon dioxide.

Ammonia is also the starting point for a few phosphatic fertilizers. For example, ammonium phosphate is derived by interaction between phosphoric acid and ammonia. Diammonium phosphate and ammoniated superphosphate also contain ammonia.

Superphosphate, the most important phosphatic fertilizer, is made by the action of sulfuric acid on insoluble phosphate rock to form a mixture of gypsum and calcium phosphate-monobasic.

USES

Figure 1 presents a breakdown of the uses of four inorganic fertilizer materials: ammonia, ammonium sulfate, phosphoric acid, and urea. It is important to note that all of these materials have non-fertilizer uses ranging from the production of fibers, plastics, resins and elastomers, to the treatment of water and waste. With the exception of ammonium sulfate, the bulk of each of these materials is used as fertilizer.

FIGURE 1

INORGANIC FERTILIZER CONSUMPTION PATTERNS

Ammonia	Fertilizers	69%
	Fibers, Plastics, Resins, Elastomers	7%
	Explosives and Blasting	3%
	Feeds	2%
	Miscellaneous Applications	10%
	Exports	9%
Ammonium Sulfate	Pulp and Paper	48%
	Treatment of Water and Waste	44%
	Miscellaneous Applications	5%
	Exports	3%
Phosphoric Acid	Fertilizers	80%
	Builders and Water Treatment	8%
	Livestock and Poultry Feeds	6%
	Foods, Beverages, Pet Foods, Dentifrices	2%
	Direct Acid Treatment of Metal Surfaces	1%
	Miscellaneous Applications	2%
	Exports	1%
Urea	Fertilizers, solid	36%
	Fertilizers, liquid	29%
	Livestock feeds	10%
	Industrial Applications	10%
	Exports	15%

Source: Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed., Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977).

INDUSTRY STRUCTURE

The fertilizer industry experienced major changes in the last 15 years as the number of fertilizer products increased dramatically and new forms of the final product were developed.[1] Companies intensified efforts to integrate both vertically and horizontally. Many nitrogen producers, for example, integrated forward to the retail level by acquiring old fertilizer outlets or building new ones. To a large extent this vertical integration eliminated the wholesaler.[2] Moves of this type were made by other chemical and petrochemical companies that were new to the fertilizer business yet concerned about securing reliable markets for their large-scale plants.[3]

Many companies also moved horizontally to acquire phosphate producers and, in some instances, potash sources. Some phosphate producers in turn entered into nitrogen production.[4]

Severe declines in the price of fertilizer eventually led to divestitures by many of the petrochemical companies. Of the sixteen that were once in business only ten were still operating at the end of 1973.[5]

Relatively speaking, concentration in the industry is low, with the top four companies out of 34 accounting for only 23 percent of the business. The top eight account for 41 percent (see Table 1).

PRICES

A summary of the Wholesale Price Index for fertilizers appears in Table 2. From 1967 to 1973, fertilizer prices exhibited an overall decline. Moderate increases in 1973 preceded dramatic price increases in 1974 and 1975, particularly for ammonia, ammonium nitrate, ammonium sulfate, phosphates and potash.[6] Prices declined somewhat in 1976 and 1977. The United States Department of Agriculture reported farm level fertilizer prices at 181 in May 1978 (1967= 100) and at 194 in May 1979.[7] Prices for selected fertilizers are presented in Table 3.

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[1] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

[2] It is not clear that another study would substantiate this statement.

[3] Meegan, Kline Guide.

[4] Ibid.

[5] Ibid.

[6] Ibid.

[7] Chemical Week, June 20, 1979.

TABLE 1

MAJOR U.S. PRODUCERS OF FERTILIZERS, 1976

RANK	COMPANY	SALES[a] (millions of dollars)
1	The Williams Companies	480
2	Farmland Industries	375
3	CF Industries	350
4	American Cyanamid	300
4	W.R. Grace	300
4	Hooker Chemical	300
4	U.S. Steel	300
8	Estech	250
9	IMC	205
10	Borden	200
10	Gardinier	200
12	Kaiser Aluminum	190
13	Allied Chemical	180
13	Kerr-McGee	180
15	Chevron Chemical	175
16	Mississippi Chemical	165
17	Cominco American	150
17	Texasgulf	150
19	Royster	140
20	Beker Industries	130
21	Valley Nitrogen	120
21	Vistron	120
23	JR Simplot	115
24	First Mississippi	110
25	Amoco	100
25	Monsanto	100
25	Olin	100
25	Union Oil of California	100
29	Indian Farm Bureau	95
30	Agway	90
30	Phillips Petroleum	90
32	Terra Chemical	70
33	Nipak	50
33	Potash Co. of America	50
--	Other	420
	Total	$6,450

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[a] Estimated sales valued at manufacturer's price.

Source: Charles Kline & Co.

Higher prices were a result of increased farm demand for fertilizers and rising production costs. Because of increases in energy prices, U.S. fertilizer production costs have been moving up at a rate of 15 to 20 percent annually.[8]

TABLE 2

FERTILIZER PRICE INDEX

(1967 =100)

Year	Fertilizer Materials	Nitrogenates	Phosphates	Potash
1978	157.4	151.0	176.1	154.1
1977	154.7	148.2	172.3	159.6
1976	181.3	159.4	217.6	172.4
1975	205.1	187.6	240.9	156.8
1974	89.2	89.6	85.2	110.9
1973	75.2	72.6	75.0	100.5
1972	71.9	67.2	75.0	98.6
1970	75.9	71.5	79.3	97.6
1968	79.4	66.8	103.1	100.3

Source: U.S. Department of Commerce, Wholesale Price Index, 1979.

SHIPMENTS

The U.S. fertilizer industry is highly volatile in terms of production and shipments. Values of shipments between 1967 and 1969 declined severely as a result of falling prices and three successive years of poor fertilizing weather, but recovered slowly thereafter until 1972.[9] Sales were up a considerable 8.7 percent in 1973 due to stronger unit demand and rising prices. Inadequate supplies, predictions of shortages and rapidly escalating prices continued to stimulate investment in fertilizer plant facilities until 1976. Unfortunately for the fertilizer industry, farmers were just experiencing falling prices for their farm products, and as a result of this and rising fertilizer prices, they sharply reduced their use of fertilizers. Inventories

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[8] Chemical and Engineering News, February 12, 1979.

[9] Meegan, Kline Guide.

TABLE 3
FERTILIZER PRICES
SHIPMENTS AND INTERPLANT TRANSFERS
(Price per Ton)

Calendar Year	Anhydrous Ammonia	Sulfuric Acid	Ammonium[a] Nitrate	Ammonium[b] Nitrate	Nitrogen Solutions	Ammonium[c] Sulfate	Urea [d]	Urea [e]	Phosphoric Acid
1947	62.69	13.13	--	--	--	48.52	--	--	162.21
1950	80.60	14.43	--	--	--	38.01	--	--	163.91
1951	84.40	16.94	--	--	114.56	44.48	--	--	180.38
1952	85.05	17.38	--	--	117.02	47.38	--	--	175.72
1953	89.41	18.70	--	--	124.10	47.47	--	--	165.50
1954	89.37	19.45	54.98	68.52	124.96	44.92	--	--	168.75
1955	84.13	19.32	55.79	66.07	123.47	44.92	101.81	--	163.15
1956	75.26	18.81	51.22	62.89	109.64	36.71	92.41	--	155.10
1957	70.92	18.40	44.21	58.88	112.35	33.16	93.78	111.09	153.82
1958	72.97	18.29	55.60	61.44	111.55	33.12	93.39	90.62	137.80
1959	69.57	19.01	43.27	60.89	115.67	33.12	93.10	100.17	148.70
1960	69.52	18.69	48.86	62.02	123.23	31.97	89.00	105.08	143.65
1961	71.83	17.95	49.14	63.54	132.38	34.34	87.25	91.93	139.99
1962	70.11	17.65	51.79	62.43	131,40	30.54	87.18	84.14	129.95
1963	68.88	17.16	48.79	60.91	119.15	27.63	84.42	87.00	124.74
1964	68.06	16.54	54.87	59.72	120.54	28.41	80.88	88.43	120.01
1965	67.45	16.68	50.99	59.03	129.25	28.01	79.96	89.35	110.77
1966	63.51	17.32	50.28	53.87	116.91	28.34	86.02	80.40	109.41
1967	54.83	18.66	45.70	52.20	111.80	29.96	73.69	82.61	111.69
1968	41.70	21.18	36.35	46.27	107.71	25.93	62.65	72.87	109.53
1969	34.02	20.98	32.60	42.13	84.99	24.53	56.11	62.19	98.30
1970	33.84	19.05	48.60	44.42	76.14	18.09	59.69	40.23	98.69
1971	34.07	19.14	48.42	44.81	83.40	16.55	52.61	55.55	91.87
1972	35.37	18.23	51.50	42.35	90.54	19.53	51.58	56.59	92.62
1973	42.68	18.34	61.77	55.82	106.03	28.00	66.51	71.08	106.60
1974	92.62	23.36	83.07	93.78	168.53	61.35	138.97	96.69	165.36
1975	148.29	32.38	116.45	117.49	230.20	71.56	152.08	126.09	180.77
1976	106.96	31.82	120.96	96.30	227.74	40.51	124.32	91.90	191.34
1977	106.53	33.05	133.48	108.68	237.24	45.29	124.83	145.19	189.16

[a] Solution, fertilizer grade.
[b] Solid, fertilizer grade.
[c] Other than coke oven.
[d] Solid fertilizer.
[e] Liquid fertilizer.

Source: U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, *The Fertilizer Supply*, 1978-1979.

grew and oversupplies forced fertilizer prices to decline.[10] The value of shipments of fertilizers in 1968, 1969, and 1976 showed decreases in shipment value of 11 percent, five percent, and four percent, respectively. The other years showed gains in value (see Table 4). In 1977, shipments were estimated to be $6,835 million, or approximately 8.3 percent of total chemical industry sales. Table 5 breaks down the value by its components.

TABLE 4

U.S. SHIPMENTS OF FERTILIZERS 1967-1977

(millions of dollars)

Year	Nitrogen compounds	Phosphates	Potash-a	Mixed Fertilizers	Total
1967	$1,031	$ 542	$ 162	$1,029	$2,770
1968	915	523	153	1,043	2,634
1969	831	421	139	943	2,334
1970	898	472	187	922	2,479
1971	901	452	214	970	2,537
1972	927	421	224	1,094	2,678
1973	1,188	443	269	1,287	3,194
1974	2,155	913	395	1,916	5,390
1975	2,937	1,209	455	2,116	6,754
1976-a	2,546	1,160	515	2,200	6,452
1976-e	2,750	1,225	535	2,325	6,835

a- includes imports for consumption.
e- estimates.

Sources: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports (Washington, D.C.: Government Printing Office, various years); U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975); U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, various years); U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years); and estimates by Charles Kline & Co.

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[10] *Ibid*.

TABLE 5

VALUE OF SHIPMENTS, 1977

(thousands of dollars)

Nitrogen compounds[a]:	$2,750
Phosphates (except phosphate rock):	1,225
Potash[b]:	535
Mixed Fertilizers:	2,325

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[a] Includes sizeable amounts used in nonfertilizer applications.

[b] Includes imported, potash as well as domestic shipments.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, N.J.: Charles Kline & Co., 1977).

The 1978 value of shipments was expected to increase approximately three percent for nitrogen and four percent for potash.[11]

The composite nature of the statistics of values of shipments can mask some important changes in its components. For example, although it is not totally clear from the value figures, fertilizer prices rose tremendously from the period 1973 to 1976, and in 1976 they decreased sharply. These changes came about because of consecutive under- and over-supply. As noted earlier, manufacturers responded to the high prices and inadequate supplies by building new plants; the result was a sharp increase in inventories and supplies. As a final result, prices dropped to significantly lower levels in 1976.

The pictures that one draws on fertilizer supply are somewhat controversial. While some sources point to real or anticipated overcapacity, there are also predictions of shortages of some fertilizer products in 1980. Edwin M. Wheeler, President of the Fertilizer Institute, predicted an increase of 53 million tons in fertilizer use for the 1979-80 fertilizer year (July 1 - June 30). Phosphorous and potash supplies are specifically predicted to be in limited supply by spring 1980[12] On the other hand, the Kline Guide states that the phosphate industry is most affected by overcapacity, and that some nitrogen overcapacity is anticipated as well.

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[11] U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

[12] Chemical Week, September 5, 1979.

Future shipments of fertilizers are forecast by the Kline Guide to increase in constant dollars by approximately 6 percent a year, reaching $7.8 billion in 1980 and $9.7 billion in 1985. The U.S. Industrial Outlook predicts an approximate 3 percent annual real growth in value of shipments with no significant increase in prices.

PRODUCTION AND GROWTH

Although chemical fertilizers have been in use since the early 19th Century, real growth in fertilizer demand occurred in the post-World War II period. During this period, there was an enormous expansion in both tonnage of primary nutrients applied to soils and in the number and complexity of materials containing nutrients. Domestic consumption rose from 4.1 million tons in crop year 1950 to 20.8 million tons in crop year 1976, an increase of more than fourfold.

The industry has undergone several major changes in recent years. In addition to a sharp increase in the number of fertilizer products, there have been significant changes made in the final form of fertilizer materials (granulated solids, liquids, etc.). These new products have resulted in new application techniques and changes to the distribution system.

Although production of selected inorganic fertilizers fluctuates from year to year, some generalizations can be made about output during the six-year period from 1974 to 1979.[13] Production of synthetic anhydrous ammonia appears to have increased slightly over the six-year period from approximately 1.2 million tons in Jauary 1974 to 1.4 million tons in October 1979. Phosphoric acid production increased substantially more than synthetic anhydrous ammonia. January 1974 output was just above 525 thousand tons. By October 1979, output increased to 796 thousand tons, an increase of 51 percent. Production of phosphatic fertilizer materials exhibited an overall increase of 41 percent during the same period from 425 thousand tons in January 1974 to more than 600 thousand tons in October 1979.

Monthly production figures of principal inorganic fertilizers from August 1977 to October 1979, are summarized in Table 6.

FOREIGN TRADE

A substantial amount of U.S.-produced fertilizer is exported to other countries, and exports are a very important part of the U.S. fertilizer industry. It is estimated that exports comprise 10 percent of all shipments.[14] Since 1973, the balance of trade in fertilizers has been consistently positive, and although a severe drop occurred in 1976, the 1977 total was $351 million (see Table 7).

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[13] These conclusions are drawn from a graph appearing in the U.S. Department of Commerce, Bureau of Census, Current Industrial Report on Inorganic Fertilizer Material and Related Products, October 1979. Precise values of earlier annual production were not available.

Phosphatic fertilizers, or phosphatics, are by far the largest dollar volume fertilizer export. In 1977, they accounted for $595 million, or 72 percent of all fertilizer exports.

Imports are mainly comprised of nitrogenous fertilizers. The negative balance of trade for this category--$237 million in 1977--has pulled down the overall positive balance of trade since 1974.

Despite some decreases in the dollar volume of exports and imports, particularly in 1975 and 1976, quantities of fertilizer exports have consistently grown. It is projected that, as foreign markets stabilize, the growth of exports will slow down but probably still continue to increase.

Apparent consumption[15] of nitrogen, phosphorous and potassium fertilizers for crop year 1977 (ended June 30) is presented in Table 8. The apparent consumption of both nitrogenous and potassium fertilizers exceeds domestic production. However, in aggregate, the U.S appears to produce about 2 million tons more than it consumes.

MISCELLANEOUS FACTS ABOUT THE INDUSTRY

Table 9 summarizes information on the number of establishments and employees; value added by manufacture; value of shipments; capital expenditures; inventories; and specialization and coverage ratios for the phosphatic and nitrogenous fertilizers.

INNOVATION

Generally speaking, fertilizers are the result of chemical reactions or mixtures as opposed to being basic, unchanging chemicals in the inorganic segments of the chemical industry. From publicly available data, it is impossible to determine how many new fertilizers, if any, are now manufactured, however, it is possible that new chemical fertilizers may result from an isolated chemical reaction process.

In view of the fairly recent dynamic nature of the fertilizer business--new products and new forms--it is possible that this trend may continue, especially as farm demand for fertilizers increases. Worldwide concern over food shortages will also have an impact on fertilizer performance in the coming years by creating additional demand.

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[14] Meegan, Kline Guide.

[15] Apparent consumption is defined as the sum of domestic production and net imports.

TABLE 6

SEASONALLY ADJUSTED PRODUCTION
SUMMARY OF PRINCIPAL INORGANIC FERTILIZERS: 1977 TO 1979

Month and Year	Ammonia, Synthetic Anhydrous (100%)	Ammonium Nitrate Original Solution	Ammonium Sulfate [a]	Nitrogen Solutions (100%)	Nitric Acid (100%)	Phosphoric Acid (100%)	Sulfuric Acid, Gross (100%)	Phosphatic Fertilizer Materials (100% P_2O_5)
1979								
October	1,443	616	(D)	(D)	689	796	3,383	609
September	1,566	594	164	(D)	647	865	3,467	671
August	1,479	640	144	(D)	690	845	3,489	690
July	1,442	627	161	210	703	883	3,592	644
June	1,505	676	167	(D)	746	883	3,466	601
May	1,456	633	188	197	706	838	3,483	643
April	1,511	668	170	184	737	827	3,488	619
March	1,470	678	188	189	751	847	3,437	630
February	1,379	604	(D)	(D)	685	815	3,411	585
January	1,396	647	(D)	193	693	804	3,133	633
1978								
December	1,564	625	134	(D)	698	828	3,256	607
November	1,506	590	(D)	179	661	805	3,361	571
October	1,394	615	147	212	707	808	3,452	631
September	1,377	563	159	202	622	813	3,419	650
August	1,298	579	176	186	663	819	3,429	639
July	1,408	560	186	207	639	791	3,236	586
June	1,398	576	171	182	648	824	3,318	564
May	1,427	594	175	177	687	802	3,367	616
April	1,499	646	173	198	694	794	3,204	563
March	1,361	677	159	203	748	785	3,203	610
February	1,334	559	158	197	628	750	3,143	553
January	1,439	621	159	224	653	735	3,240	588
1977								
December	1,487	543	(D)	234	606	648	2,659	498
November	1,492	601	(D)	238	642	624	2,703	498
October	1,446	603	143	220	656	717	2,979	602
September	1,594	653	130	259	681	735	2,963	635
August	1,511	629	188	251	706	716	2,904	602

Note: The seasonally adjusted series shown in this table have been revised to reflect revisions to 1977. The new seasonal factors were published in the June 1977 report. Beginning in January 1972, the data are adjusted for report period variation. Comparable data are not available for previous years; however, the effect of this adjustment is considered to be negligible at the total level. See "Reporting Period Adjustment" in the text.

(D) Withheld to avoid disclosing figures for individual companies.

[a] Excludes byproduct ammonium sulfate, coke oven.

Source: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports: Inorganic Fertilizer Materials and Related Products, October 1979.

TABLE 7

FERTILIZERS

BALANCE OF TRADE

(thousands of dollars)

	1977	1976	1975	1974	1973	1965
Value of Exports						
Nitrogenous Fertilizers	138,000	120,168	251,371	167,949	100,881	64,653
Phosphatic Fertilizers	595,008	519,746	833,580	626,246	269,067	55,241
Mixing Fertilizers	96,908	30,284	40,695	53,476	34,084	12,985
Total	830,716	670,198	1,125,646	847,671	404,032	132,879
Value of Imports						
Nitrogenous Fertilizers	377,975	240,380	279,656	205,256	95,248	29,124
Phosphatic Fertilizers	55,739	61,562	77,822	73,639	39,128	15,560
Mixing Fertilizers	45,012	33,949	69,906	104,595	22,361	11,985
Total	478,726	335,891	427,384	383,490	156,737	56,669
Balance of Trade [a]						
Nitrogenous Fertilizers	-239,175	-120,212	-28,285	-37,307	5,663	35,529
Phosphatic Fertilizers	539,269	458,184	755,758	552,607	229,939	39,681
Mixing Fertilizers	51,896	-3,665	-29,211	-51,119	11,723	1,000
Total	351,990	334,307	698,262	464,181	247,295	76,210

[a] Exports minus imports.

Source: U.S. Department of Commerce, U.S. Exports, FT 610, and U.S. Imports, FT 210, various years.

TABLE 8

SUPPLY AND CONSUMPTION OF FERTILIZERS, CROP YEAR 1977

(thousands of tons, nutrient basis)

	Production	Imports	Exports	Apparent Consumption
Nitrogen (N)				
Ammonia	4,643	592	345	4,890
Ammonium nitrate a/	1,115	118	2	1,231
Ammonium sulfate	487	119	104	502
Urea	883	346	206	1,023
Other	3,534	252	562	3,224
Total	10,662	1,427	1,219	10,870
Phosphorous (P_2O_5)				
Ammonium phosphates a/	3,587	152	1,292	2,447
Concentrated superphosphate	1,677	18	585	1,110
Normal superphosphate	371	--	1	370
Other	1,748	54	467	1,335
Total	7,383	224	2,345	5,262
Potassium (K_2O)				
Potassium chloride	2,075	4,226	927	5,374
Potassium sulfate a/	412	45	161	296
Other	35	24	26	33
Total	2,522	4,295	1,114	5,703
GRAND TOTAL	20,567	5,946	4,678	21,835

a/--Includes ammonium nitrate and ammonium nitrate-limestone mixtures.

Source: U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, The Fertilizer Supply, 1978-79.

TABLE 9

FERTILIZER INDUSTRY STATISTICS

Year[1]	All Establishments		All Employees		Production Workers						Assets and Expenditures			Ratios	
	Total (number)	With 20 Employees or more (number)	Number (1,000)	Payroll (million dollars)	Number (1,000)	Hours (millions)	Wages (million dollars)	Value added by Manufacture (million dollars)	Cost of materials (million dollars)	Value of shipments (million dollars)	New Capital Expenditures (million dollars)	Gross value of fixed assets (million dollars)	End-of-Year inventories (million dollars)	Specialization ratio (percent)	Coverage ratio (percent)
INDUSTRY 2873, NITROGENOUS FERTILIZERS															
1977 Census	119	88	12.0	205.1	7.7	16.8	126.6	1,193.0	1,433.8	2,578.4	846.0	3,047.5	377.0	94	72
1976 ASM	(NA)	(NA)	11.3	189.8	7.4	16.7	115.8	1,238.6	1,171.7	2,384.5	604.7	2,526.9	290.9	(NA)	(NA)
1975 ASM	(NA)	(NA)	10.6	160.8	7.1	15.2	98.8	1,582.4	968.9	2,500.3	400.0	2,006.3	238.4	(NA)	(NA)
1974 ASM	(NA)	(NA)	10.1	132.6	7.1	14.8	84.8	1,141.3	671.1	1,789.4	155.6	1,582.6	152.1	(NA)	(NA)
1973 ASM	(NA)	(NA)	9.2	113.1	6.3	13.8	74.3	500.2	448.0	970.4	104.4	1,440.6	106.9	(NA)	(NA)
1972 Census	76	69	9.4	104.3	6.1	13.2	64.3	447.6	362.7	799.4	33.2	1,403.3	116.2	r94	r69
INDUSTRY 2874, PHOSPHATIC FERTILIZERS															
1977 Census	92	68	14.6	212.8	10.1	21.7	139.0	818.5	1,919.0	2,663.9	111.8	1,810.9	420.2	93	91
1976 ASM	(NA)	(NA)	14.9	201.5	10.7	22.5	130.5	726.9	1,696.0	2,439.1	225.6	1,616.0	370.6	(NA)	(NA)
1975 ASM	(NA)	(NA)	16.0	199.6	11.7	24.7	135.2	1,178.8	1,685.6	2,746.9	302.2	1,492.7	378.8	(NA)	(NA)
1974 ASM	(NA)	(NA)	14.8	162.4	11.1	24.0	111.2	1,028.1	1,247.9	2,222.4	297.7	1,090.9	233.3	(NA)	(NA)
1973 ASM	(NA)	(NA)	13.1	128.0	9.6	20.8	88.4	543.6	795.6	1,357.5	88.3	811.8	129.8	(NA)	(NA)
1972 Census	145	115	14.9	135.1	10.8	23.1	91.9	426.4	740.9	1,178.9	65.8	771.5	157.8	89	92

rRevised. (NA) Not available.

[1] In years of Annual Survey of Manufactures (ASM), data are estimates based on a representative sample of establishments canvassed annually and may differ from results of a complete canvass of all establishments. ASM publication shows percentage standard errors. This industry was newly defined for 1972 Census of Manufactures so no comparable data prior to 1972 exist.

Sources: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures, Washington, D.C.: Government Printing Office, 1979).

Of course, the argument could be made that fertilizer manufacturers, concerned with rising production costs, will focus on process improvements instead of on new products. At this point of our analysis, it is unclear if either trend will materialize, and which, if any, will dominate. Industry interviews may provide more information on fertilizer innovation.

Inoganic Pigments

INORGANIC PIGMENTS

OVERVIEW OF THE INORGANIC PIGMENT INDUSTRY

This section describes the chemistry of inorganic pigments and a history of the industry's development. Later sections discuss in greater detail processing, industry structure, and the raw materials used in production.

There are three major product categories of inorganic pigments:

- prime white pigments,
- color pigments, and
- extender pigments.

The following subsections briefly describe the production chemistry and typical uses of pigments in each category.

Prime White Pigments

White pigments are the largest volume and dollar category, accounting for 59 percent and 63 percent of total dollar shipments of inorganic pigments in 1976 and 1977, respectively.[1] They are used for their whiteness and opacity which are expressed either individually or in combination with other pigments and colorants. The two most important white pigments are titanium dioxide (TiO_2) and zinc oxide (ZnO_2) which accounted for 78.2 percent ($626.7 million) and 18.6 percent ($149.1 million), respectively, of the total $801.5 million in sales for white pigments in 1977.[2] Other products in this group include white lead (lead sulfate or carbonate), leaded zinc oxide, antimony oxide, lithopone (a mixture of zinc sulfate and barium sulfite) and zinc sulfide.[3]

The metallic oxide white pigments, TiO_2 and ZnO_2 (as well as other colored metallic oxide pigments) are made in a continuous slurry process by a reaction of the appropriate metal in the presence of acid. The metal is not in its elemental state, but is in an ore body or alloy form. For example, titanium dioxide is made by reacting either rutile or ilmenite--both titanium ores--with sulfuric acid or chlorine.[4] Only nine plants constitute the entire industry, with plant capacities ranging from 164,000 to over 2,000,000 pounds per day.[5]

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[1] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977); and U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

[2] U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing

[3] The leaded pigments have been banned from household paints since the early 1970s and their sales for uses in this area declined. For example, the white lead sales volume in 1976 was less than .1 percent of all white pigment sales and was largely for export. Source: Meegan, Kline Guide.

Several of the white pigments have properties that make them especially attractive in particular applications. Zinc oxide in paint is an effective fungicide. Additionally, it has photoconductive properties and is used to coat reprographic papers for photocopying. Antimony oxide, because of its relatively high cost compared to TiO_2, is rarely employed as an opacifying agent. Instead, it is used as a flame retardant in plastics.

Color Pigments

Color pigments are the second largest group by dollar sales, accounting for 30.7 percent and 33.3 percent of the total dollar shipments of inorganic pigments in 1976 and 1977, respectively.[6] Among the color pigments shown in Table 1, the chrome pigments, as a group, are the largest in dollar volume.

Chrome pigments are made by roasting chromite ore with soda ash and lime. This yields an intermediate powder, sodium dichromate, which is then reacted with various metals in the presence of strong acids to yield the pigments. The larger volume colorants are produced through a continuous process in relatively large plants. For example, the average litharge facility produced slightly more than 50,000 pounds of pigment per day in 1977.[7]

Because of the wide range of colors and physical and chemical properties, color pigments have wide application. Chrome yellow and molybate orange pigments are used to color plastics as well as serve as colorants in paint. Zinc yellows and red lead are used in primers to resist corrosion. Litharge's major use is in storage battery plates and as a glass additive. Cuprous oxides are employed in antifouling marine paints, and cadmium sulfides and selenides have high temperature applications. Iron oxide pigments are used in magnetic tape coatings.

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[4] In this example, as well as with other processes using acids, waste acid disposal presents a problem. Recent environmental problems have mandated pollution control equipment which add to processing costs.

[5] Chemical Marketing Reporter, October 16, 1978.

[6] U.S. Department of Commerce, 1977 Census of Manufactures; and Meegan, Kline Guide.

[7] U.S. Department of Commerce, 1977 Census of Manufactures.

TABLE 1

SALES OF COLOR METALLIC PIGMENTS: 1976, 1977

Color Pigment	Sales (millions of dollars)	
	1976[a]	1977[b]
Chromes		
Yellow and Orange	45	49.7
Green	3	--
Oxide green	14	12.2
Molybate Orange	26	28.2
Zinc Yellow	6	4.6
Litharge (lead monoxide)	67	67.3
Red lead (lead oxide)	11	7.8
Ceramic Colors	80	48.8
Iron oxides	46	--
Iron blues	9	5.6
Other colors	123	
Total	430	447.6

[a] Meegan, Kline Guide.

[b] U.S. Department of Commerce, 1977 Census of Manufactures.

Extender Pigments

Extender pigments have little or no opacity, but are generally less expensive to use than metallic oxides. Paper is coated with extenders to improve gloss and "inkability". In paints, they can affect sheen, coat thickness, and uniformity of pigment dispersion, and settling.

Most extender pigments are mined products such as kaolin, calcium carbamate, talc and asbestos. They are sold as minerals with no chemical processing and, therefore, are not discussed here. Other extenders, such as precipitated silicates (sodium metasilicate, sodium orthosilicate, and sodium sesquisilicate), fine particle silicas and aluminum hydrates are chemically produced. There are substantial differences in publicly reported data for sales of extender pigments. The Kline Guide reports that an estimated one million tons of chemically produced extender pigments were sold, valued at $140 million in 1976.[8] In conflict, the 1977 Census of Manufactures reports 83,000 tons sold, valued at 37.5 million in 1977.[9] There are no other publicly available sources that confirm either number. However, the Census data reported purchases of raw material non-metallic minerals (clay, talc, limestone, barite, potash, etc.) of only $12.2 million. The Bureau of Mines Minerals Yearbook (1976) reports sales of talc and kaolin alone of $8.3 million for paints, which tends to make the Census data estimates lower than actual.

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[8] Meegan, Kline Guide, p. 154.

The extenders are produced by a variety of methods. One of the largest volume extenders, aluminum hydroxide, is made by the Bayer process, reacting bauxite ore in the presence of sodium hydroxide to form a solution from which aluminum hydroxide is extracted. This extender is used extensively in carpet backing where it contributes flame retardant properties.

Another high volume extender pigment, precipitated calcium carbonate, is made from limestone by roasting the limestone in a continuously run oven, treating the resulting calcium oxide with a strong base to form calcium hydroxide, and precipitating the pigment with further acid treatment. This extender is used in paper coatings to improve brightness and "printability".

Chemically, most pigments from all categories are insoluble in inorganic and water base solvents. In their final state, they are highly inert, generally non-toxic except for lead pigments (and then only if ingested) and will not react with other chemicals except strong acids or bases. As their name implies, they are called pigments because they impart color (including white and black) through mechanical mixing rather than through a chemical reaction.

While pigments have many uses today, the earliest use was as a colorant. As early as 3000 B.C., a paint industry flourished in Mesopotamia (an ancient country northwest of the Persian Gulf), and has continued in various configurations since that time.[10] Initially, minerals that possessed natural colors (typically iron oxides) were ground and mixed with a liquid or applied as a powder. The advent of synthetic inorganic pigments occurred when minerals were treated with acids in 1857.

The age of this industry has resulted in a steady, slow growth industry, and, except for extender pigments, manufacturing has become very concentrated. In 1976, the four largest producers (each with sales of over $100 million in 1976) accounted for 54 percent of industry shipments and the 10 largest, listed in Table 2, accounted for 80 percent of the total.[11]

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[9] U.S. Department of Commerce, 1977 Census of Manufactures.

[10] Will Durant, The Story of Civilization (New York: Simon and Schuster, 1935-), Vol. III.

[11] Meegan, Kline Guide.

TABLE 2

MAJOR U.S. PRODUCERS OF SYNTHETIC INORGANIC PIGMENTS: 1976

Rank	Company	Sales (millions of dollars)
1	DuPont	315
2	NL Industries	160
3	Glidden	120
4	New Jersey Zinc	100
5	Hercules	85
6	American Cyanamid	80
7	St. Joe	60
8	Harshaw	35
9	Asarco	30
10	Kerr-McGee	30
11	Eagle Picher	25
12	Ferro	20
	Other	215
	Total	1,275

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

Other uses include the plastics, paper, paper board and printing ink industries. Table 3 shows the relative value of sales to major users of inorganic pigments in 1977.

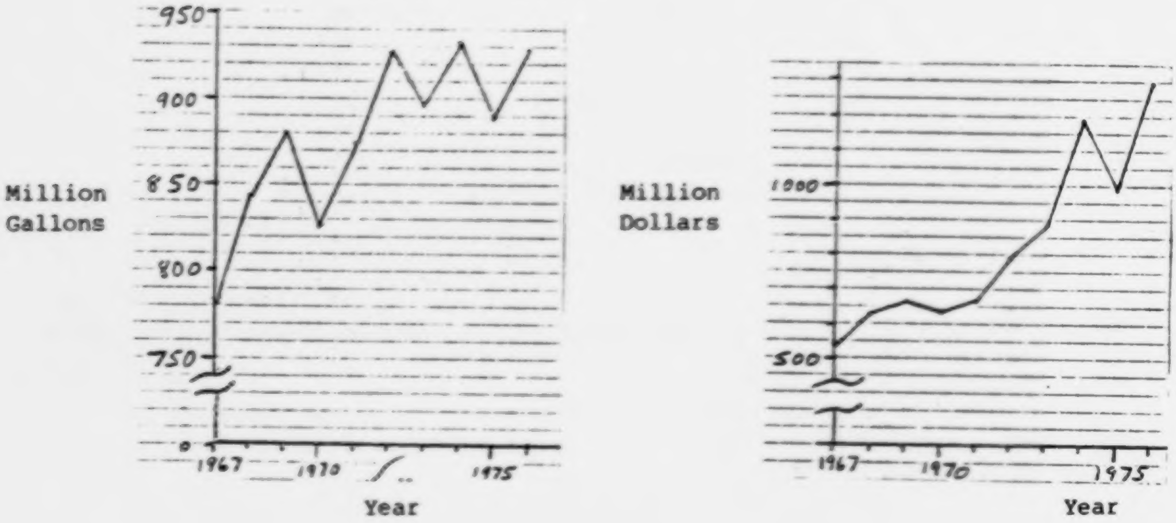
RAW MATERIALS

In 1977, all inorganic pigment production consumed $560.7 million in raw materials, up from $333.1 million in 1972. Table 4 presents the major raw material groups consumed in production in 1977, and where available, the respective quantity, value, and per annum price increase from 1970 to 1976 of each group. Comparable data for earlier years is not available.

Inorganic pigments serve as raw materials for many other industries, with the largest user being paint manufacturers (more than one-third of sales in 1977).12/

FIGURE 1

U.S. SHIPMENTS OF PAINTS AND PIGMENTS 1960-1976



Paint Sales

Pigment Sales

Sources: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports (Washington, D.C.: Government Printing Office, various years); and U.S Department of Commerce, Bureau of Census, Annual Survey of Manufacturers (Washington, D.C.: Government Printing Office, various years).

12/Ibid.

TABLE 3

MAJOR USERS OF INORGANIC PIGMENTS: 1977

Industry	Percent of Total Pigment Sales	Value ($ Millions)
Paint & Allied Products	38.8	472.0
Plastics	2.5	30.0[a]
Paper and Paperboard	22.4	351.0[a]
Printing Ink	15.2	184.8

[a] Actual figure probably is much larger, but data is incomplete.

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

The largest single raw material cost is for titanium ore. The two major resources for TiO_2 are rutile, imported from Australia, and ilmenite, more than 90 percent of which is produced domestically.[13] There are indications that the Australian supply of rutile may become exhausted within 10 to 15 years, and ilmenite could substitute.[14] The ilmenite ore is converted by the sulfate process which, as previously mentioned, is highly polluting, while rutile is transformed by the less polluting chlorine process. Thus, a shift from rutile to ilmenite would increase overall production costs by increasing pollution control costs.

Table 5A presents the cost trends for imports of TiO_2 ore. As with many other raw materials,[15] there has been a rapid expansion in cost since the mid-1970s due to increased extraction and transportation costs.

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[13] U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

[14] Ibid., p 123.

[15] U.S. Department of Commerce, 1978 U.S. Industrial Outlook; and Chemical and Engineering News, October 16, 1978.

TABLE 4

MAJOR RAW MATERIAL GROUPS CONSUMED: 1977

Material Group	Quantity (tons 1000)	Value ($ millions)	Per annum price increse 1970 - 1976
Acids	396.6	12.9	
Other Inorganic Chemicals	76.0	8.8	14.0
Industrial Gases		3.9	2.0
Plastic Powers, pellets & Ganules	8.25	6.5	14.2
Crude Ores:			
Non-ferrous (except titanium ore)	238.2	34.1	24.2[a] 28.4[b]
Ferrous	--	5.2	14.9
Titanium	--	100.2	14.1
Non-metallic minerals	--	12.2	--
All other parts, supplies	--	311.6	--

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[a] Phosphate rock.

[b] Chromite.

Sources: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.; Government Printing Office, 1979); and U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, 1970 and 1976).

TABLE 5A

TITANIUM DIOXIDE IMPORTS AND SELECTED PRICES: 1976-1978

Year	Import Value ($ millions)	Price Per Ton	Amount Imported (thousand tons)
1970	22.2	82.33	269.6
1971	15.7	-	-
1972	33.4	-	-
1973	27.5	-	-
1974	24.8	167.48	148.1
1975	18.3	-	-
1976	45.3	214.42	212.3
1977	80.1	-	-
1978-e	95.0	-	-

e- estimates

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Imports, FT 210; U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, various years); and Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 5B

IMPORTS, EXPORTS AND PRICES OF CHROMITE ORE: 1971-1976

(tons, thousands of dollars)

Year	Exports	Imports	Average Price/ton
1971	35	1299	25.00
1972	20	1056	22.72
1973	21	931	30.00
1974	18	1102	33.00
1975	139	1252	82.00
1976	124	1275	107.66

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, various years).

Other metallic ores, notably chromite, are largely imported. Table 5B indicates the import, export, and price trends in chromite ore from 1972 through 1976. These figures show a rapid price increase after 1972.

Chromite is imported mainly from the USSR, Turkey and South Africa. While the reserves of ore from these countries are large enough to supply domestic needs for several centuries at present consumption rates, political and economic instability such as the recent changes in Soviet-American diplomacy, have led to increased stockpiling. The possible impact of changes in relationships with any of these supplier countries is hard to predict, but a substantial lessening of supply from any one of these countries could cause a substantial increase in raw material prices.

PRICES, PRODUCTION, AND EMPLOYMENT

With few exceptions, inorganic pigments are commodity chemicals sold in relatively large volumes to composition specifications that are standard throughout the industry. Because there is little differentiation in the quality of a product, it appears that competition is based largely on price and, as a result, prices in this mature segment tend to approach costs, with producers relying on reductions of processing costs to increase margins. While data on the identity of the producers and aggregate amounts of products sold are publicly available, the relative profit margins and overall contribution to profits is not available for any single producer.

Increases in raw material prices, largely due to higher extraction, processing and transportation costs that are directly or indirectly linked to energy costs have, in recent years, put upward price pressure on all inorganic pigment products. Table 6 examines the price indices trends of several major inorganic pigments between 1967 and 1976. While there is year to year variation from 1967 to 1973, all prices rose sharply in the three years following 1973, reflecting sharp increases in energy costs. The average per annum price increase between 1970 and 1976 was 11.5 percent.

As indicated in Table 4, the majority of raw materials used underwent price increases greater than 11.5 percent between 1970 and 1976, indicating there could be an overall reduction in profit margins. This margin squeeze can be examined in greater detail by looking at the trends in the amount of value added each year. Also, trends in the real value of shipments indicate industry growth and the effects on capacity utilization. Finally, trends in the relative costs of materials, labor, and value added will indicate the total cost situation that the industry faces.

TABLE 6
INDICES OF AVERAGE MANUFACTURERS' PRICES OF SELECTED INORGANIC PIGMENTS: 1967-1976
(1967=100)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Titanium dioxide	100.0	100.0	100.0	97.3	88.8	93.5	99.8	132.3	143.8	163.6
Zinc oxide	100.0	99.6	107.6	98.9	115.5	123.8	126.4	223.8	260.3	248.0
Chrome yellow and orange	100.0	102.2	103.0	109.3	113.2	111.0	109.7	160.5	183.1	197.8
Litharge	100.0	102.2	103.0	109.3	113.2	111.0	109.7	160.5	183.1	197.8
Iron oxides[a]	100.0	101.6	103.8	96.5	105.3	111.9	125.3	193.9	227.6	254.2
Red lead	100.0	103.8	106.4	114.0	105.6	107.3	114.9	155.0	147.7	169.0
Iron blues	100.0	101.0	98.9	103.0	111.9	135.3	139.7	168.0	187.1	209.0
Calcium carbonate[b]	100.0	104.1	102.8	104.6	110.0	114.8	116.7	142.6	155.6	172.2
AVERAGE	100.0	101.1	103.2	101.1	98.4	102.6	108.8	153.5	165.2	194.4

[a] Excludes natural iron oxides.

[b] Precipitated grades only.

Source: Calculated from data of U.S. Department of Commerce, Bureau of Census, Current Industrial Reports (Washington, D.C. Government Printing Office, various years); and U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, (Washington, D.C.: Government Printing Office, various years).

Table 7 illustrates the trends in payroll costs and value added both as a percent of shipments, and in material costs. The table indicates that new value added, which includes profits, has steadily declined. Table 8 examines the dollar volume of shipments, showing the relative stagnation of industry sales. The maturity and stability of the industry has resulted in little net change in the amount of labor employed. Also, there has been little real increase in overall average value added per production worker. Table 9 shows trends in employment and value added per production manhour from 1972 through 1978.

TABLE 7

TRENDS IN EMPLOYMENT AND MATERIALS EXPENDITURE
IN THE INORGANIC PIGMENTS SEGMENT: 1967-1977

	(Percent of Shipment)		
Year	Material	Payroll	Value Added
1977	55.8	8.7	44.9
1976	55.2	8.3	45.3
1975	55.5	10.3	47.4
1974	54.0	10.2	49.7
1973	49.6	11.4	48.0
1972	50.1	11.0	50.0
1971	49.3	12.8	52.1
1970	45.5	12.8	55.9
1969	43.4	11.8	57.1
1968	42.8	11.1	57.6
1967	42.6	11.5	58.4

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 8

SALES OF INORGANIC PIGMENTS IN CURRENT AND CONSTANT DOLLARS FOR 1967-1977

Year	Shipments ($ Millions)	Shipments (1972 $ millions)[a]
1977	1256.0	894.6
1976	1292.5	973.2
1975	988.9	782.4
1974	1188.6	1016.8
1973	890.2	843.8
1972	796.9	796.9
1971	666.0	689.4
1970	646.0	698.4
1969	657.7	758.4
1968	624.0	755.7
1967	549.3	695.1

[a] Adjusted using GNP deflator, 1972 index.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 9

PRODUCTION WORKER EMPLOYMENT AND AVERAGE VALUE-ADDED: 1972-1978

Year	Production Employees	Value Added Per Production Manhour (constant 1972 dollars)[a]
1972	9,000	21.00
1973	9,600	19.66
1974	11,000	22.07
1975	10,300	18.56
1976	10,600	19.67
1977	10,500	23.89
1978	11,000	18.55

[a] Adjusted using GNP deflator, 1972 index.

Source: U.S. Department of Commerce, 1978 U.S. Industrial Outlook, (Washington D.C.: Government Printing Office, 1978)

Forecasts by several sources do not predict significant changes in these trends.[16]

COMPETITION

Sales of the inorganic pigments industry are relatively concentrated, with a small number of producers accounting for a large percentage of total sales. As previously discussed, the top 10 producers of inorganic pigments accounted for 80 percent of shipments. This fact, coupled with the large overall amount of pigments shipped, means that the 10 producers mentioned in Table 2 shipped an average of 4,110 tons per day in 1978.[17] The large capital investment necessary to achieve these volumes has created an effective barrier to entry for new domestic competitors. For example, in 1975, Kerr-McGee started construction of a synthetic rutile plant which was completed in 1976. The plant's design capacity is 110,000 tons/year, and it was built with an estimated $90 - 100 million dollars.[18] With a total industry volume of 750,000 tons of titanium dioxide in 1979, Kerr-McGee's large investment captured less than 15 percent of the market.

However, foreign competitors have placed increasing competitive pressure on domestic producers by lowering their prices. Subsidization by their respective governments in the form of reduced taxes, tariffs, and secured loans; access to plentiful raw materials; and less restrictive environmental constraints have combined to give many new entrants the ability to gain market share.[19]

As a result, imports of inorganic pigments have been growing more rapidly than exports, resulting in wider trade deficits. Table 10 illustrates this trend, which is expected to continue.

While the chemical industry as a whole is a leader in R&D spending compared to all manufacturing, there are very few new annual product additions in the inorganic pigment segment. No publicly available data indicates the amounts of money spent annually for R&D in this segment. Since approximately 90 percent of total annual expenditures in the overall chemical industry is

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[16] U.S. Department of Commerce, 1978 U.S. Industrial Outlook; and Chemical and Engineering News, October 16, 1978.

[17] U..S. Department of Commerce, 1978 U.S. Industrial Outlook.

[18] ICF estimates from data in SEC 10-K reports for 1974, 1975, 1976. The resulting capital cost per pound of rutile, assuming a 20 year plant life, is 23¢ per pound, while the market price is 59¢ per pound. Source: Chemical Engineering News, July 16, 1979.

[19] U.S. Department of Commerce, 1978 U.S. Industrial Outlook.

TABLE 10

U.S. IMPORTS AND EXPORTS OF SYNTHETIC INORGANIC PIGMENTS: 1969-1976

(millions of dollars)

Year	Imports	Exports	Trade Balance
1969	46	37	- 9
1970	46	43	- 3
1971	59	46	-13
1972	46	39	- 7
1973	77	62	-15
1974	100	93	- 7
1975	68	60	- 8
1976	124	87	-37

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Farifield, NJ: Charles Kline & Co., 1977).

for applied or development research, it is reasonable to expect that the majority of R&D expenditures for the pigment industry is on process applications.[20]

Rising raw material, energy, and pollution control costs imply that most of future R&D efforts will be toward reducing these costs through more efficient and less polluting processes. Because of the capital intensity of these high volume processes, radical changes in processes probably do not occur as often as minor changes.

Organic pigments face similar rising raw material and energy costs.[21] Thus, changes in market share are unlikely to occur by substitution with organic products or by improved production techniques, but may result from price competition with competitors.

20/National Science Foundation, Graduate Science Education: Student Support and Post Doctoral, Publication number 74-318, Fall 1973.

21/Discussed in detail in the profile on Organic Dyes and Pigments.

All Other Inorganic Chemicals

ALL OTHER INORGANIC CHEMICALS

DESCRIPTION

The all other inorganic chemicals segment of the chemical industry includes alkalies and chlorine; aluminum, potassium and sodium compounds; and inorganic acids. By Standard Industrial Classification (SIC) code, this segment is comprised of the "281" industries except for industrial gases (2813), inorganic pigments (2816), and chemical catalytic preparations (28198).

In general, inorganic chemicals are produced from minerals. They are usually solid, non-combustible, and soluble in water.

ENGINEERING PROCESS

The engineering processes used to manufacture inorganic chemicals vary. For example, some chlor-alkalies may be produced by the electrolysis of brine or by chemical or thermal reaction. Others, such as caustic soda, are byproducts or coproducts of some other chemical's production.[1] Rapidly escalating costs of synthetic soda ash production have all but eliminated facilities using the Solvay method of saturating brine with ammonia and carbon dioxide gas to make soda ash.[2] New soda ash plants now produce the chemical more cheaply from a natural source--trona ore. The trona process involves calcination of a sodium carbonate/sodium bicarbonate mixture to convert the bicarbonate portion of the trona into carbonate.

The production of inorganic acids utilizes entirely different processes from those used to manufacture the chlor-alkalies and sodium compounds. Nitric acid results from the oxidation of ammonia with a platinum catalyst. Sulfuric acid, derived from sulfur, pyrites, sulfide smelter gases, and hydrogen sulfide, are produced in several ways. The "Cat-ox" procedure, a proprietary catalytic oxidation process, removes sulfur dioxide and fly ash from stack gases and converts the sulfur dioxide to sulfuric acid. The widely used contact process involves the oxidation of sulfur dioxide with air by contact with a vanadium pentoxide catalyst. This process yields sulfur trioxide which is then absorbed in high strength sulfuric acid to yield a product of 98 to 100 percent acid.

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[1] The production of chlorine and caustic soda is highly interrelated. Electrolytic processes yield both chemicals in a fixed ratio of 1.1 tons of caustic per ton of chlorine gas.

[2] In 1974 there were six giant Solvay process facilities with an annual aggregate output of four million tons of soda ash. By mid-1979, only one, a 900,000 ton unit owned by Allied Chemical, remained in operation (Business Week, April 16, 1979).

USES

Most of the inorganic chemicals produced today date back to the late eighteenth century and have well established end uses. They are employed primarily as processing aids in the manufacture of chemical and non-chemical products. In most cases, they do not appear as final products.

Many inorganic chemicals are used to produce organic chemicals as well as other inorganics. Numerous other industries rely on inorganics: pulp and paper, aluminum, rayon/cellophane, petroleum, detergents, water treatment, pharmaceuticals, etc. Except for chlorine and a few others, inorganics are not used extensively in synthetic products such as plastics and fibers.

Figure 1 presents a breakdown of end uses for five chlor-alkalies (chlorine, potassium hydroxide, sodium bicarbonate, sodium carbonate, and sodium hydroxide) and three other inorganics (calcium chloride, hydrofluoric acid and sulfuric acid).

Almost two-thirds of chlorine is consumed in the production of organic chemicals. The remainder is utilized in pulp and paper production, inorganic chemical production, and sanitizing processes. Chlorine is one of the most important chemicals used as a raw material in producing polyvinyl chloride (PVC) and other plastics as well as solvents, intermediates and bleaches. The demand for end-products like PVC determines to a large extent chlorine's volume of sales. Demand for PVC is sensitive to the housing and automotive markets; thus, chlorine as an intermediate in PVC is sensitive to these markets as well as to overall changes in the economy.

Soda ash is used in virtually every industry from dishwashing detergents to fiberglass insulation. Fifty percent of all soda ash is consumed by the glass industry; therefore, soda ash, like chlorine, is quite sensitive to the construction and automotive markets. Other major alkalies are also affected by changing economic conditions, but to a lesser degree than chlorine and soda.[3]

INDUSTRY STRUCTURE

In general, the inorganic chemicals industry does not attract a large number of producers due to the maturity of its products and moderate rates of growth. Prior to 1974 inorganic chemicals kept pace with GNP, but industry experts believe that in the future inorganics will grow at a rate slightly less than the gross national product (GNP).[4]

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[3] Chemical Purchasing, October 1979.

[4] George M. Tapps and William T, Hewitt, "Industry Outlook for Inorganic Chemicals," Chemical Engineering, June 6, 1977.

FIGURE 1

USES OF INORGANIC CHEMICALS

CHLORINE

Organic chemicals	60.0%
vinyl chloride	
chlorethane solvents	
propylene oxide	
pesticides	
fluorocarbons	
Pulp and paper	13.0%
Inorganic chemicals	11.0%
Sanitization of potable and waste water in municipal waterworks and sewage plants	5.0%

POTASSIUM HYDROXIDE

Potassium carbonate	28.0%
Soaps	18.0%
Tetrapotassium pyrophosphate	18.0%
Other potassium chemicals	10.0%
Liquid fertilizers	8.0%
Dyestuffs	5.0%
Herbicides	4.0%
Miscellaneous applications	5.5%
Exports	3.5%

FIGURE 1
USES OF INORGANIC CHEMICALS
(continued)

SODIUM BICARBONATE

Food (baking powder) industry	33.0%
Rubber and industrial chemicals	20.0%
Pharmaceutical	15.0%
Fire extinguishers	10.0%
Soaps, detergents, animal, feeds, textile, paper, leather, and exports	12.0%

SODIUM CARBONATE (caustic soda)

Glass	51.0%
Chemicals	22.0%
Pulp and paper	6.0%
Soap and detergents	5.0%
Water treatment	3.0%
Miscellaneous applications	6.0%
Exports	7.0%

FIGURE 1

USES OF INORGANIC CHEMICALS

(continued)

SODIUM HYDROXIDE

Chemical and metal processing (other than aluminum)	46.0%
Paper and pulp manufacture	16.0%
Petroleum, textile, soap, food industries	12.0%
Aluminum processing	5.0%
Rayon and cellophane production	4.0%
Miscellaneous applications	7.0%
Exports	10.0%

HYDROFLUORIC ACID

Fluorocarbons	41.0%
Aluminum smelting:	37.0%
aluminum fluoride	25.0%
synthetic cryolite	12.0%
Gasoline alkylation catalyst	4.0%
Stainless steel pickling	3.0%
Fluoride salts	3.0%
Uranium isotope separation	2.0%
Miscellaneous applications	10.0%

FIGURE 1
USES OF INORGANIC CHEMICALS
(continued)

CALCIUM CHLORIDE

Dust control	27.0%
Deicing highways	26.0%
Industrial processing	21.0%
Concrete treatment	10.0%
Oil well drilling	5.0%
Tire ballasting	3.0%
Miscellaneous applications	4.0%
Exports	4.0%

SULFURIC ACID

Phosphate fertilizers	52.0%
Other fertilizers	3.0%
Ammonium sulfate	6.0%
Petroleum refining	5.0%
Titanium dioxide	4.0%
Alcohols	4.0%
Hydrofluoric acid	3.0%
Copper leaching	3.0%
Miscellaneous applications	20.0%

Source: Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed., Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977).

Compared to organics, the inorganics industry has a smaller number of producers and a higher concentration of sales among larger companies. The top four chlor-alkali firms accounted for 72 percent of shipments in 1972, and for other industrial inorganics, the top four accounted for almost 35 percent of shipments.[5]

Specifically, eight companies produce about 75 percent of U.S. chlorine; the remainder is produced by 23 companies. The soda ash industry is also highly concentrated. In 1977 seven companies produced soda ash, but with recent closings of synthetic ash plants, only five producers may remain. In 1977 there were almost 70 producers of sulfuric acid, with the five largest sharing 30 percent of the market. One phosphoric acid company held a 12 percent share of industry capacity. The top five producers of phosphoric acid are estimated to have 40 percent of the total market, which has 30 producers all together. In contrast to these industries, there are no dominant producers of nitric acid. Five producers have 38 percent of industry capacity while 41 smaller firms share the remaining 62 percent.[6]

Of the 100 leading U.S. chemical producers, 64 manufacture basic and intermediate inorganics.[7] Fourteen of the 64 produce only sulfur (11 are petroleum companies, three are agricultural chemical producers). The remaining are either considered true chemical companies with more than 50 percent of sales in chemicals, or long-time producers of chemicals.[8]

Several large chemical companies appear to concentrate in inorganics instead of organics: Diamond Shamrock, FMC Corporation, Freeport Minerals, Kerr-McGee, NL Industries, Occidental Petroleum through its Hooker subsidiary, Olin, PPG, and Stauffer Chemical. Other major producers of inorganics are Allied Chemical, American Cyanamid, BASF Wyandotte, Dow Chemical, DuPont, Monsanto, Pennwalt and Union Carbide.[9]

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[5] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

[6] Tapps and Williams, "Industry Outlook for Inorganic Chemicals."

[7] Eighty-one out of the 100 engage in the production of basic and intermediate organic chemicals.

[8] Meegan, Kline Guide.

[9] Ibid.

SHIPMENTS

Inorganic chemicals represented 9 percent, or about $9 billion, of the total shipments of all chemicals in 1976.[10] In 1977, shipments of alkalies and chlorine by primary manufacturers totaled almost $1.7 billion, three percent below the 1976 total. Shipments of inorganic chemicals other than chlor-alkalies, pigments and fertilizer chemicals, totaled $6.5 billion. Inorganic acids, other than nitric and sulfuric acid, contributed $369 million or 6 percent of this total, and aluminum oxide, exclusive of natural alumina, contributed $827 million or 13 percent. Other aluminum compounds constituted $314 million or five percent, and potassium and sodium compounds (except bleaches, alkalies and alums) constituted $1.4 billion or 22 percent (refer to Table 1). Other products contributing to the $6.5 billion figure are chemical catalytic preparations; chemical reagents; and compounds of antimony, arsenic, barium, bismuth, cadmium, and calcium, chromium, cobalt, copper, manganese, mercury, and nickel, phosphorus and other less common elements.[11]

PRICES

In general, before 1973 the average price of many inorganic chemicals rose more slowly than the costs of labor and energy. The price of chlor-alkalies began climbing in 1974 after price decontrol and continued to rise through 1977.[12] Price increases were attributed largely to higher costs of labor, fuel and electric power, and raw materials.

The magnitude of price increases in this period varied. Between 1973 and 1976, the price of native sulfur jumped 221 percent while the price of aluminum sulfate increased by 58 percent.[13] These increases were due largely to shortages in the supply of these products.

The price of liquid chlorine rose dramatically in 1974 from $74 per ton on January 4, 1974 to $140 by year-end, an increase of 87 percent. Caustic soda also experienced a sharp increase from $76 per ton to $120, a rise of

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[10] Tapps and Williams, "Industry Outlook for Inorganic Chemicals."

[11] U.S. Department of Commerce, Bureau of Census, Current Industrial Reports: Inorganic Chemicals (Washington, D.C.: Government Printing Office, 1977).

[12] Meegan, Kline Guide.

[13] U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

TABLE 1

INORGANIC CHEMICALS

VALUE OF SHIPMENTS INCLUDING INTERPLANT TRANSFERS

(thousands of dollars)

SIC Code	Product	1977	1976	1975	1974	1973
2812	Alkalies and Chlorine	1,681,442	1,728,676	1,562,478	1,191,878	855,718
28121	Chlorine	501,275	524,741	442,193	333,238	238,774
28122	Sodium carbonate (soda ash)	144,700	155,315	165,941	157,534	131,028
28123	Sodium hydroxide (caustic soda)	973,229	982,836	890,883	663,505	452,636
2819	Inorganic chemicals, NEC, total	6,543,384	5,941,573	5,017,522	4,791,198	3,644,127
28193	Sulfuric acid	404,587	380,323	368,723	320,452	241,535
28194	Inorganic acids, except nitric and sulfuric	369,271	295,935	231,682	214,294	174,343
28194-11	Boric acid	45,043	31,355	23,451	14,159	13,344
28194---	Hydrochloric acid	111,732	68,123	50,142	45,372	41,622
28195-11	Aluminum oxide, except natural alumina	827,520	749,636	590,051	618,926	453,160
28196	Other aluminum compounds	314,556	287,117	233,827	220,108	183,256
28197	Potassium and sodium compounds (except bleaches, alkalies, and alums)	1,419,754	1,323,357	1,161,658	962,209	730,696

Source: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports: Inorganic Chemicals, 1977.

58 percent.[14] These increases were due to shortages in the supply of these products.

According to one source, the price of soda ash was stable between 1955 and 1969 at $31 per ton, freight on board (F.O.B.) producing point. In 1970 the price moved to $33 and, after price decontrol in 1974, prices spiraled to $75 per ton in the East and $51 in the West. In August 1977 a firm price of $55 per ton for dense bulk ash was established.[15] Price increases were attributed to high production costs and water pollution regulations. The leveling-off of prices after 1977 represents somewhat the shift to natural soda ash and more efficient production technologies.

Table 2 summarizes the Wholesale Price Index for various inorganic chemicals. Most of the chlor-alkalies have doubled in price since 1967. Other inorganic chemicals have increased in price by as little as 13 percent (calcium phosphate) or as much as 162 percent (sodium tripolyphosphate).

PRODUCTION AND GROWTH

With the exception of synthetic soda ash, caustic soda and smaller-volume inorganics, production of chlor-alkalies and other inorganics has been increasing steadily since 1973 (refer to Table 3). However, in aggregate, most of the markets are operating under capacity. Table 4 presents annual production and capacity figures for high-volume inorganics. None were being produced at full-capacity in 1977 and 1978.

Chlorine production, for example, was at 76.5 percent of capacity in December 1977. The reason behind this is that chlorine producers overbuilt plants before demand growth fell way below forecasts, and producers have continued to push up capacity each year faster than production has grown.[16] Improvement in capacity use occurred in 1978; the Chlorine Institute listed capacity use at 82.5 percent by year end. However, new capacity that came on stream in 1979, plus a slowdown in the U.S. economy, was expected to lower the operating rate to less than 80 percent in 1979. Low profitability in the chlorine industry will likely dampen future plant investments and provide industry with a chance to return to higher operating rates after 1980. In addition, some existing capacity may be shut down as

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[14] Ibid.

[15] Chemical Purchasing, June 1978; and U.S. Department of Commerce, 1978 U.S. Industrial Outlook.

[16] Chemical and Engineering News, February 26, 1979.

TABLE 2
INORGANIC CHEMICALS
WHOLESALE PRICE INDEX
(1967=100)

	1978	1977	1976	1975	1974	1974	1973	1971	1970
Basic Inorganic Chemicals	193.0	187.2	177.3	154.0	101.0	110.3	107.9	107.0	115.3
Alkalies and Chlorine	202.1	204.4	202.8	165.5	100.1	114.6	114.4	112.5	114.6
Chlorine Liquid	207.6	211.7	200.9	167.8	N/A	111.1[a]	111.1	111.1	119.1
Potassium Hydroxide	200.4	193.5	188.3	164.7	101.1	123.1	123.1	118.0	128.0
Sodium Carbonate	183.9	179.9	153.1	132.8	103.3	114.5	114.5	106.4	106.4
Sodium Hydroxide	212.4	216.9	229.5	179.6	98.2	117.7	117.7	117.7	114.7
Other Inorganic Chemicals	190.5	181.3	168.1	149.8	101.3	110.2	106.9	105.8	118.5
Aluminum Fluoride	141.3	138.0	125.4	100.0	N/A	100.0	100.0	N/A	N/A
Aluminum Hydroxide	123.0	118.2	105.1	101.7	N/A	100.0	100.0	N/A	N/A
Aluminum Oxide	146.7	135.9	109.0	107.5	N/A	113.2	113.2	110.4	N/A
Aluminum Sulfate	190.3	173.7	157.1	124.5	98.2	134.1	123.4	123.4	136.0
Calcium Carbide	129.2	120.3	117.0	104.0	N/A	100.0	100.0	100.0	117.6
Calcium Oxide	201.2	187.3	170.2	147.7	N/A	113.4	114.3	110.2	111.3
Calcium Phosphate	113.1	112.8	104.2	N/A	N/A	104.9	100.0	111.1	111.6
Hydrochloric Acid	177.0	152.8	128.9	130.0	101.1	86.7	86.7	106.7	116.7
Hydrofluoric Acid	151.5	139.9	140.1	117.7	99.9	143.6	143.6	130.8	103.3
Hydrogen Peroxide	115.5	116.9	102.7	99.2	100.0	84.1	94.1	94.1	84.4
Nitric Acid 42 degrees BE	175.5	185.0	180.3	166.6	97.5	106.4	106.4	106.4	100.0
Sodium Hydrosulfite	116.6	105.8	111.9	104.2	N/A	115.6	109.9	109.9	117.6
Sodium Metasilicate	169.8	152.5	N/A	102.1	N/A	N/A	N/A	N/A	N/A
Sodium Silicates	196.5	170.8	162.2	124.5	100.8	146.2	134.7	123.2	125.0
Sodium Sulfate, Anhydrous	207.9	243.1	227.4	180.0	101.9	100.0[b]	100.0	100.0	100.0
Sodium Tripolyphosphate	261.9	153.6	N/A	216.9	100.0	121.3	114.4	111.6	94.7
Sulfuric Acid (contact) 66 BE	166.1	164.0	164.7	147.9	102.9	118.8	111.9	111.9	144.5

[a] This is the figure for all chlorine.

[b] This figure is for all sodium sulfate.

N/A - Not available.

Source: U.S. Department of Commerce, Wholesale Price Index, 1979.

TABLE 3
QUANTITY OF PRODUCTION
(thousands of short tons)

Product Class	Chemical	1977	1976	1975	1974	1973
28121 11	Chlorine gas	10,573	10,378	9,167	10,753	10,402
28121 15	Chlorine liquid	6,341	6,091	5,317	5,652	5,426
28122 51	Synthetic soda ash	1,812	2,344	2,802	3,507	3,813
28122	Natural soda ash	6,278	5,216	4,353	4,048	3,707
28123	Caustic soda	10,933	10,516	9,634	11,188	10,734
28124 21	Caustic potash	301	252	236	208	220
28193	Sulfuric acid	35,821	33,300	32,360	33,936	31,949
28194 11	Boric acid (boracic)	177	135	133	140	144
28194 40	Hydrochloric acid	2,721	2,542	2,009	2,470	2,534
28194 51	Hydrocyanic acid	198	182	151	176	161
28194 61	Hydrofluoric, anhydrous	179	182	213	261	249
28195 11	Aluminum oxide, except natural alumina	5,948	5,720	5,057	6,950	6,751
28196 17	Aluminum Chloride, anhydrous	45	34	27	37	37
28196 25	Aluminum hydroxide, tethydrate	N/A	488	421	532	607
28196 27	Aluminum fluoride, technical	148	142	130	169	140
28196 51	Commercial aluminum sulfate	1,255	1,202	1,141	1,252	1,227
28196 55	Iron free aluminum sulfate	123	174	252	232	230
28197 13	Potassium iodide	.8	.7	.5	1.2	1.1
28197 16	Potassium sulfate	494	465	456	430	463
28197 18	Pyrophosphate	41	40	41	40	45
28197 21	Sodium (metal)	159	146	144	173	177
28197 24	Sodium borate	N/A	N/A	N/A	587	603
28197 27	Sodium chlorate	218	199	173	203	204
28197 29	Sodium hydrosulfide	20	21	24	30	28
28197 30	Sodium hydrosulfite	64	60	50	56	49
28197 38	Tripolyphosphate	717	724	770	903	967
28197 61	High purity sulfate	741	766	796	783	907
28199 04	Barium carbonate, precipitated	35	36	26	40	48
28199 10	Isolated bromine	164	156	143	155	N/A
28199 12	Calcium carbide	252	244	253	324	290
28199 13	Calcium carbonate, precipitated	175	142	202	267	242
28199 74	Sulfur, recovered elemental (long ton)	3,567	3,138	2,969	2,632	2,416
28199 75	Sulfur dioxide	153	162	146	130	110

Source: U.S. Department of Commerce, Bureau of Census, Current Industrial Reports: Inorganic Chemicals, 1977.

TABLE 4

INORGANIC CHEMICALS

ANNUAL PRODUCTION AND CAPACITY

(thousands of short tons)[a]

Product	Annual Capacity		Production		
	1/1/77	1/1/78	1976	1977	1978
Ammonia, anhydrous	18,750	22,462	16,450	17,295	19,093
Caustic soda	13,895	14,704	10,160	11,975	12,514
Chlorine	13,400	14,042	9,040	10,692	11,173
Nitric acid	10,497	10,370	7,790	7,866	8,141
Phosphoric acid, wet	8,650	8,740	7,350	7,330	7,110
Potash[b]	11,500	11,999	7,975	9,000	9,405
Soda ash	10,315	10,590	7,124	7,938	8,176
Sodium chlorate	264	285	196	211	226
Sodium sulfate	1,443	1,640	923	1,261	1,299
Sodium phosphates	1,499	1,400	890	881	855
Sulfur, frasch	7,900	8,350	6,365	5,911	6,136
Sulfuric acid	47,177	49,210	32,350	34,304	36,019

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[a] Sulfur figures in thousands of long tons.

[b] Figures for U.S. and Canada.

Source: Chemical Marketing Reporter, January 2, 1978.

some companies attempt to balance the tradeoff between economies of plant size and increasing overhead costs, such as those due to environmental regulations.17/

Caustic soda also has a dismal capacity record (see Table 5).

As noted earlier, the production of chlorine and caustic soda is highly interrelated: electrolytic processes yield both at a fixed ratio of 1.1 tons of caustic soda per ton of chlorine gas. In effect, caustic soda growth has been forced by vigorous attempts at chlorine caustic plants to meet chlorine demand. The result is a parallel increase in caustic output whether the market wants it or not. At present, demand for caustic is slack: aluminum production has been sluggish and labor disputes in the U.S. pulp and paper industry have helped reduce caustic demand because of uncertainties about production. To compound matters, demand for caustic soda appears to be elastic, as soda ash is a substitute for caustic.18/ This means that caustic producers are limited in the amount by which they can raise prices to cover costs.

In contrast to the chlorine and caustic soda markets, supplies of soda ash are very tight at consuming points. Operating rates are also much higher for soda ash (see Table 6).

The tightness in supply is due partly to transportation difficulties (e.g., freight car unavailability and adverse weather conditions). Delivery became a critical factor in the supply of soda ash when plant sites were shifted from old synthetic plants in the East to natural ore deposits in the West. With approximately 70 percent of domestic soda ash production consumed east of the Mississippi,19/ transportation was destined to become a constraining factor. In addition to these transportation difficulties, over one million tons of synthetic soda ash capacity was shut down, which tightened supplies even further. Although forecasts for 1980 were not available at this writing, production of soda ash was expected to rise a modest three to four percent in 1979.20/

For other inorganic chemicals, future production trends and growth rates rest largely on end-product market conditions. Sulfuric acid's largest use, for example, is in the production of phosphoric acid for subsequent use in phosphatic fertilizers. About two-thirds of all phosphoric acid is used to this end; therefore, the market for phosphatic fertilizers determines to a

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17/Chemical Purchasing, October 1979.

18/Ibid.

19/Chemical Purchasing, June 1978.

20/Chemical and Engineering News, February 26, 1979.

TABLE 5
CAUSTIC SODA
PRODUCTION AND CAPACITY
(thousands of tons)

Year	Production	Average Annual Capacity	Operating Rate
1979 E	11,685	16,400	71.3%
1978 E	11,290	15,860	71.2%
1977	10,933	14,685	74.5%
1976	10,516	13,665	77.0%
1975	9,635	13,035	73.9%
1974	11,189	12,140	92.2%
1973	10,734	11,210	95.8%

E- estimated.

Source: Chemical Purchasing, April 1979.
(From information provided by the Chemical Research Group of the First Boston Corporation.)

TABLE 6
SODA ASH
PRODUCTION AND CAPACITY
(thousands of tons)

Year	Production	Average Annual Capacity	Operating Rate
1979 E	8,595	9,595	89.6%
1978 E	8,380	9,535	87.9%
1977	8,040	9,880	81.4%
1976	7,560	9,705	77.9%
1975	7,130	8,760	81.4%
1974	7,566	8,390	90.2%
1973	7,535	8,260	91.2%

E- estimated.

Source: Chemical Purchasing, April 1979.
(From information provided by the Chemical Research Group of the First Boston Corporation.)

large extent the fate of the sulfuric acid industry.[21]

Sodium sulfate serves as another example of how production is tied to end markets; the bulk of sodium sulfate production goes to the pulp and paper industry. Recently, increased environmental pressure forced the industry to recover and recycle some of the material lost in the production process. As a result, use of sodium sulfate by the pulp and paper industry is expected to decline.

FOREIGN TRADE

The inorganic chemicals business to a large extent depends upon foreign trade. In 1975, 15.4 percent of the total shipments of inorganic chemicals was exported.[22] At a disaggregated level, however, exports in many cases appear to be relatively small. For example, trade in many of the basic inorganic chemicals like sulfuric acid, hydrochloric acid, phosphates, and potassium and sodium compounds is often small.[23] Trading partners often prefer to import or produce basic mineral products like potash and phosphate rock and then produce inorganic chemicals themselves .

A comparison between the value of exports (Table 7) and the value of domestic shipments (Table 8) shows that in 1977 the U.S. exported less than 9 percent of its inorganic acids , 11 percent of its chlor-alkalies, and 17 percent of its potassium and sodium compounds.[24]

Caustic soda and sodium carbonate are the major items in chlor-alkali exports. The bulk of caustic soda exports goes to countries in which subsidiaries of U.S. aluminum companies operate (caustic soda is an intermediate in aluminum production) and also to Canada, Mexico, Brazil and Argentina.

Table 11 suggests that the United States has been able to maintain a positive balance of trade in chlor-alkalies and potassium and sodium

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[21] Chemical and Engineering News, March 27, 1978.

[22] Meegan, Kline Guide.

[23] U.S. Department of Commerce, 1978 U.S. Industrial Outlook. (Note: It is unclear whether "small" refers to volume or value.)

[24] For a detailed breakdown of export and import values by product class, see Tables 9 and 10.

TABLE 7

INORGANIC CHEMICALS: VALUE OF EXPORTS

(thousands of dollars)

Chemical Product & SIC Code	1977	1976	1975	1974	1973	1965
Alkalies and Chlorine SIC 2812	185,120	159,703	210,286	152,374	81,401	35,118
Inorganic Acids SIC 2819 3, 4	31,815	26,194	24,727	20,558	15,479	8,612
Potassium and Sodium Compounds SIC 2819 7	247,055	218,399	230,539	184,112	123,268	79,060
Other Inorganic Chemicals, NEC SIC 2819 5, 6, 9	963,831	920,412	676,660	543,781	535,933	147,991

Source: U.S. Department of Commerce, U.S. Exports, FT 610.

TABLE 8

INORGANIC CHEMICALS: VALUE OF IMPORTS

(thousands of dollars)

Chemical Product & SIC Code	1977	1976	1975	1974	1973	1965
Alkalies and Chlorine SIC 2812	35,377	25,375	29,255	26,280	13,984	3,243
Inorganic Acids SIC 2819 3, 4	71,369	59,368	32,090	25,535	20,366	2,583
Potassium and Sodium Compounds SIC 2819 7	48,182	42,855	35,055	34,381	23,556	13,769
Other Inorganic Chemicals, NEC SIC 2819 5, 6, 9	1,058,791	993,967	1,091,623	506,400	393,433	64,833

Source: U.S. Department of Commerce, U.S. Imports, FT 210.

TABLE 9

VALUE OF EXPORTS

(dollars)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Alkalies and Chlorine	2812	185,120,453	159,702,909	210,285,923	152,374,345	81,400,986	35,117,844
Chlorine	2812 10 00	11,048,429	5,183,292	4,020,559	3,196,982	1,390,767	2,353,556
Sodium Carbonate (Soda ash)--except natural	2812 20 20	52,943,416	47,003,527	45,822,262	34,156,479	16,064,159	9,029,526
Sodium Bicarbonate	2812 20 40	3,152,771	3,077,876	2,469,777	2,084,113	2,156,719	N/A
Sodium Hydroxide--Solid	2812 30 20	5,918,615	13,064,022	39,384,733	33,981,255	17,614,515	10,953,692
Sodium Hydroxide--Liquid	2812 30 40	107,261,839	87,654,443	116,208,665	76,020,902	42,445,594	12,056,168
Potassium Hydroxide	2812 40 10	3,558,971	2,811,020	2,094,751	1,602,888	1,220,714	665,613
Alkalies, NEC	2812 40 97	1,236,412	908,729	285,176	1,331,726	508,518	52,289
Inorganic Acids	2819	31,815,221	26,194,273	24,726,975	20,557,732	15,478,834	8,612,110
Sulfuric Acid (Oleum)	2819 30 00	2,295,744	1,910,434	4,762,872	3,022,909	754,046	439,937
Boric Acid	2819 40 10	12,957,553	12,362,932	11,480,994	8,773,999	9,343,732	2,947,099
Hydrochloric and Chlorosulfonic Acids	2819 40 25	1,963,956	1,706,296	1,510,860	1,519,436	880,752	N/A
Chromium Oxides, Anhydrides etc., except pigment grades	2819 40 40	7,411,400	5,518,399	3,997,752	3,630,209	2,687,131	N/A
Inorganic Acids, NEC	2819 40 97	7,186,568	4,696,212	2,974,497	3,611,179	1,813,173	5,225,074
Potassium and Sodium Compounds	2819	247,054,724	218,398,762	230,538,582	184,111,842	123,268,467	79,059,594
Potassium Compounds	2819 70 20	105,046,359	108,350,457	108,595,389	78,945,625	67,199,501	41,828,302
Sodium Sulfate--Crude and Refined	2819 70 22	2,801,225	3,635,573	6,144,006	3,250,046	2,048,535	415,140
Sodium Borates--Refined	2819 70 23	64,633,664	49,156,150	42,486,333	33,836,394	19,353,562	13,975,248
Sodium Cyanide	2819 70 25	5,749,446	4,052,833	2,939,410	3,931,924	2,155,671	1,289,489

TABLE 9
VALUE OF EXPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Potassium and Sodium Compounds (continued)							
Sodium Hydrosulfite	2819 70 35	4,460,926	2,472,075	2,975,421	3,633,984	1,513,111	603,109
Sodium Phosphate--Mono-, Di-, Meta-, Pyro-	2819 70 40	13,891,524	12,700,839	14,527,904	13,103,394	6,496,936	4,620,956
Sodium Compounds, NEC	2819 70 79	38,236,067	26,344,222	25,021,569	27,215,939	17,738,114	9,313,476
Other Inorganic Chemicals, NEC	2819	963,830,733	920,412,051	676,660,312	543,781,466	535,932,682	147,990,612
Aluminum Oxide	2819 50 00	94,208,776	122,299,994	96,087,101	72,378,253	63,179,884	25,106,093
Aluminum Hydroxide	2819 60 15	9,104,504	7,935,036	5,694,056	4,947,419	3,897,565	2,208,745
Aluminum Sulfate	2819 60 20	889,789	1,568,521	2,897,072	1,807,486	642,181	500,705
Aluminum Compounds, NEC	2819 60 97	17,575,126	21,028,815	16,307,074	16,838,625	14,095,970	4,115,258
Calcium Carbonate, Precipitated, except pigment grades	2819 9c 11	4,052,482	735,017	704,917	1,541,445	1,088,076	N/A
Calcium Chloride	2819 9c 13	3,383,075	2,578,448	2,313,555	1,699,039	2,224,715	N/A
Dicalcium Phosphate	2819 9c 17	9,549,970	7,611,636	6,269,534	6,864,360	4,752,759	N/A
Activated Carbon	2819 9c 20	12,941,413	13,050,858	13,307,134	14,034,970	8,650,971	3,520,050
Sodium Bichromate and Chromate	2819 9c 24	7,975,766	6,397,863	4,569,124	3,283,553	3,373,582	862,285
Bleaching Compounds, NEC Inorganic	2819 9c 55	22,369,563	19,046,344	15,148,132	13,676,569	12,997,778	2,617,715
Elemental Phosphorus	2819 9c 58	20,722,041	30,387,005	36,659,382	20,075,306	12,255,716	N/A
Tin Oxides	2819 9c 81	453,601	466,867	511,907	443,398	401,935	281,834
Chemicals & Chemical Elements, NEC (Including Special Nuclear Material)--Inorganic	2819 9c 97	760,604,627	687,305,647	476,191,324	386,191,043	408,371,550	108,777,927

Source: U.S. Department of Commerce, U.S. Exports of Domestic Merchandise, 1978.

TABLE 10
VALUE OF IMPORTS
(dollars)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Alkalies and Chlorine	2812	35,377,265	25,374,779	29,255,181	26,279,814	13,983,732	3,243,222
Chlorine	2812 10 00	11,806,888	10,737,459	8,903,595	7,293,932	3,327,434	2,394,782
Sodium Carbonate, Calcined	2812 20 20	148,097	2,246	341,078	3,258,345	756,101	N/A
Sodium Bicarbonate	2812 20 40	454,521	153,388	78,580	330,930	260,120	276,911 a/
Sodium Hydroxide	2812 30 00	21,291,616	13,338,948	16,141,054	13,742,628	8,870,759	336,101
Potassium Hydroxide	2812 40 10	372,506	288,021	2,721,108	752,379	295,177	193,585
Potassium Bicarbonate and Carbonate and Sodium Carbonate, Hydrated	2812 40 98	1,303,637	854,717	1,069,766	901,600	474,141	41,843
Inorganic Acids	28193, 28194	71,368,688	59,367,672	32,089,870	25,535,390	20,365,767	2,582,705
Sulfuric Acid	2819 30 00	8,075,372	7,974,642	5,339,227	7,826,004	5,260,180	667,124
Boric Acid	2819 40 10	5,588,041	14,201	59,339	176,074	3,015	1,616
Hydrochloric Acid	2819 40 20	4,305,560	3,131,187	2,327,345	2,409,772	2,940,878	820,943
Hydrofluoric Acid	2819 40 30	44,890,463	40,975,644	20,336,992	12,080,281	9,823,468	14,166
Arsenic Acid, Tungstic Acid and Inorganic Acids, NES	2819 40 98	8,509,252	7,271,998	4,026,967	3,043,259	2,338,226	1,078,856

a/ Includes Sodium Carbonate and Bicarbonate.

TABLE 10
VALUE OF IMPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Potassium and Sodium Compounds	28197	48,481,981	42,854,936	35,055,183	34,380,997	23,555,573	13,769,331
Potassium Iodide	2819 70 05	183,378	120,927	108,720	137,031	91,820	300
Potassium Nitrate	2819 70 10	154,985	38,282	196,671	31,358	97,020	154,675
Potassium Compounds, NES	2819 70 19	7,772,332	6,951,601	6,547,943	8,047,093	4,852,002	2,343,667
Sodium Borate, Other than Crude	2819 70 23	23,375	3,744	2,625	109,564	--	--
Sodium Cyanide	2819 70 25	4,761,485	3,482,715	2,971,464	2,704,132	1,729,476	2,625,203
Sodium Chlorate	2819 70 30	11,036,262	4,305,321	3,259,894	3,258,285	3,226,395	334,831
Sodium Hydrosulfite	2819 70 35	3,094	39,787	66,305	61,970	8,892	22,261
Sodium Phosphate and Pyrophosphates	2819 70 40	243,650	165,439	3,111,227	906,721	2,094,394	125,510
Sodium Silicate	2819 70 45	142,917	26,750	11,666	11,253	4,156	223,319
Sodium Silicofluoride	2819 70 50	394,467	609,926	1,023,343	796,356	445,593	426,295
Sodium Sulfate, Crude or Salt Cake	2819 70 55	5,936,324	11,592,364	8,304,796	7,132,557	4,054,032	4,521,280
Sodium Sulfate, Anhydrous	2819 70 60	6,697,753	6,959,707	4,318,562	3,220,254	1,601,526	242,646
Sodium Sulfide	2819 70 70	5,025	141,346	113,542	119,196	--	--
Sodium Compounds, NES	2819 70 89	11,126,934	8,417,027	5,018,425	7,816,061	5,348,067	2,749,082
Sodium Sulfate, Crystallized or Glaubers Salt	2819 70 65	--	--	--	29,166	2,200	262
Aluminum Hydroxide and Oxide or Alumina	2819 50 00	511,350,880	404,058,338	370,038,900	270,616,984	209,329,453	15,941,087

TABLE 10
VALUE OF IMPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Other Inorganic Chemicals, NEC	2819 5,6,9	1,058,790,812	993,966,830	1,091,623,273	506,400,065	393,432,810	64,833,104
Aluminum Sulfate	2819 60 20	1,586,010	1,220,491	911,107	751,694	704,931	335,217
Sodium Aluminate	2819 60 30	11,196	1,368	6,050	--	29,002	88,450
Cryolite or kryolith	2819 60 40	4,311,771	4,332,140	9,057,929	6,968,721	5,103,646	2,008,551
Aluminum compounds, NES, Including Ammonium	2819 60 98	5,388,897	4,539,962	2,220,708	2,631,624	4,019,253	783,316
Antimony Compounds	2819 9c 01	12,769	9,640	5,965	24,739	147,977	214,591
Arsenic Compounds	2819 9c 02	2,658,596	1,733,113	4,516,400	2,504,503	2,149,384	1,280,608
Barium Compounds, Precipitated	2819 9c 03	1,393,921	422,857	110,861	1,723,063	1,603,186	53,452
Barium Compounds, NES	2819 9c 05	2,896,267	1,932,862	2,272,683	8,912,055	3,543,139	329,833
Bismuth Compounds	2819 9c 06	44,200	35,382	47,897	182,570	40,957	25,338
Bromine	2819 9c 07	102,059	23,520	1,248	796,956	--	--
Calcium Carbide	2819 9c 09	1,258,809	926,319	1,037,010	518,697	740,495	728,381
Calcium Carbonate, Precipitated	2819 9c 11	1,205,686	551,095	242,426	450,520	332,063	164,188
Calcium Chloride	2819 9c 13	1,073,342	681,462	597,758	155,727	316,507	99,751
Calcium Cyanide	2819 9c 15	340,409	441,903	375,228	373,879	585,411	1,462,639
Calcium Hypochlorite	2819 9c 16	306,983	682,856	897,912	148,384	209,079	N/A
Dicalcium Phosphate	2819 9c 17	8,771	181,140	45,592	1,342,544	174,659	N/A
Calcium Compounds, NES	2819 9c 19	10,505,889	7,254,689	11,328,203	10,675,590	7,215,927	2,549,156

TABLE 10
VALUE OF IMPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Other Inorganic Chemicals, NEC (continued)							
Potassium Chromate and Dichromate	2819 9c 22	4,699	4,597	24,622	344,955	2,495	11,553
Sodium Chromate and Dichromate	2819 9c 24	62,903	240,929	373,699	1,253,593	244,665	3,204,887
Cobalt Oxide, Sulfate and Compounds, NES	2819 9c 26	2,720,375	931,864	852,658	4,526,531	2,751,663	1,173,276
Copper or Cupric Oxide	2819 9c 27	869,568	748,631	526,520	--	24,612	N/A
Cuprous Oxide	2819 9c 28	759,340	364,261	805,274	1,455,535	751,427	489,742
Copper Sulfate	2819 9c 29	1,213,319	537,248	192,541	295,695	304,379	131,449
Copper Cyanide, Iodide, and Compounds, NES	2819 9c 31	450,457	241,271	699,883	468,452	302,484	245,621
Gold Compounds	2819 9c 33	19,553	85,770	20,078	7,411	--	29,400
Hydrogen Peroxide	2819 9c 35	2,731,063	3,305,349	415,529	800,196	1,013,280	414,089
Iodine	2819 9c 36	13,949,953	13,870,615	11,792,956	14,929,787	10,622,960	2,478,477
Iron Sulfate	2819 9c 37	334,586	144,196	58,213	119,127	76,605	N/A
Iron Compunds, NES	2819 9c 38	1,490,549	2,138,635	823,461	1,139,745	258,959	191,301
Lead Nitrate	2819 9c 40	112,568	140,256	110,115	164,675	37,700	45,072
Lead Compounds, NES	2819 9c 42	168,630	86,430	61,140	61,062	99,722	11,201
Magnesium Sulfate	2819 9c 43	1,387,720	1,095,762	1,070,557	701,557	962,338	597,914

TABLE 10
VALUE OF IMPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Other Inorganic Chemicals, NEC (continued)							
Magnesium Oxide, Carbonate, Chloride, and Compounds, NES	2819 9c 45	1,684,433	1,154,599	725,679	1,410,354	920,613	418,600
Manganese Sulfate	2819 9c 46	18,890	15,671	1,300	3,768	8,585	7,136
Manganese Borate and Compounds, NES	2819 9c 48	3,652,404	2,372,754	841,561	1,724,543	1,286,545	241,636
Mercury Compounds	2819 9c 51	87,549	57,659	35,476	51,247	30,530	85,118
Molybdenum Compounds and Sodium Molybdate	2819 9c 53	95,808	256,345	230,627	322,003	614,066	553,259
Nickel Sulfate	2819 9c 54	559,332	815,026	254,391	58,814	177,208	65,949
Nickel Chloride, Oxide, and Compounds, NES	2819 9c 56	17,265,643	22,291,903	15,212,029	15,230,055	13,442,975	14,990,241
Phosphorus	2819 9c 58	1,461,751	1,633,674	1,615,145	1,214,227	744,692	293,368
Phosphorous Oxychloride	2819 9c 59	467,960	367,639	781,048	128,293	N/A	N/A
Phosphorous Trichloride	2819 9c 60	37,017	50,485	70,474	243,422	N/A	N/A
Phosphorous Compounds, NES	2819 9c 62	984,354	707,786	1,350,632	609,152	303,854	74,038
Platinum Compounds	2819 9c 64	352,000	1,668,385	2,068	59,645	67,344	3,857
Selenium Compounds	2819 9c 67	687,178	377,888	464,401	510,012	961,752	131,733
Silver Compounds	2819 9c 70	4,402,109	419,248	2,569,602	656,168	78,567	153,251
Strontium Carbonate, Nitrate, Oxide, and Compounds, NES	2819 9c 72	556,828	2,039,260	1,124,687	2,433,630	1,301,727	2,490

TABLE 10
VALUE OF IMPORTS
(dollars)
(continued)

Description of Chemical	SIC Code	1977	1976	1975	1974	1973	1965
Other Inorganic Chemicals, NEC (continued)							
Sulfur Dioxide	2819 9c 74	4,086,295	2,840,400	2,389,830	2,225,276	2,024,195	104,345
Thallium Compounds	2819 9c 78	483,463	16,833	8,636	4,308	4,030	9,210
Tin Tetrachloride	2819 9c 79	1,170	--	--	--	--	N/A
Tin Dichloride	2819 9c 80	249,577	132,435	91,362	291,181	81,424	N/A
Tin Compounds, NES	2819 9c 82	1,187,180	1,040,930	732,383	866,555	546,145	355,983
Titanium Compounds	2819 9c 84	813,771	1,067,438	1,206,432	497,660	372,680	211,933
Tungsten Compounds	2819 9c 85	2,921,039	2,219,764	1,725,696	1,563,215	1,392,146	22,932
Zinc Chloride	2819 9c 86	1,032,355	700,861	517,778	1,263,859	535,803	185,886
Zinc Sulfate	2819 9c 87	1,762,703	1,614,815	1,065,180	2,439,138	698,621	304,954
Zinc Arsenate, Cyanide, Hydrosulfite, and Compounds, NES	2819 9c 89	919,566	653,226	781,001	2,305,596	843,424	517,099
Lime chlorinated with not more than 40% of Available Chlorine	2819 9c 95	67,329	59,051	29,058	49,873	24,826	82,904
Other Elements and Inorganic Compounds, NES	2819 9c 98	442,221,370	496,427,804	207,105,995	135,191,499	113,272,708	10,928,642

Source: U.S. Department of Commerce, U.S. Imports for Consumption and General Imports, 1978.

TABLE 11

INORGANIC CHEMICALS

BALANCE OF TRADE: EXPORTS-IMPORTS

(thousands of dollars)

Chemical Product & SIC Code	1977	1976	1975	1974	1973	1965
Alkalies and Chlorine SIC 2812	149,743	134,328	181,031	126,094	67,417	31,875
Inorganic Acids SIC 2819 3, 4	-39,554	-33,174	-7,363	-4,977	-4,887	6,029
Potassium and Sodium Compounds SIC 2819 7	198,873	175,544	195,484	149,731	99,712	65,291
Other Inorganic Chemicals, NEC SIC 2819 5, 6, 9	-94,960	-73,555	-414,963	37,381	142,500	83,158

Source: Calculated from Tables 9 and 10.

TABLE 12

ECONOMIC INDICATORS

Year[a]		All Establishments		All Employees		Production Workers			Value Added			Assets and Expenditures			Ratios	
		Total (number)	With 20 Employees or more (number)	Number (1,000)	Payroll (million dollars)	Number (1,000)	Hours (millions)	Wages (million dollars)	Value added by Manufacture (million dollars)	Cost of materials (million dollars)	Value of shipments (million dollars)	New Capital Expenditures (million dollars)	Gross value of fixed assets (million dollars)	End-of-Year inventories (million dollars)	Specialization ratio (percent)	Coverage ratio (percent)
		INDUSTRY 2812, ALKALIES AND CHLORINE														
1977	Census	48	32	11.8	215.4	7.9	16.0	135.0	805.4	823.4	1,663.2	186.6	1,692.1	141.		
1976	ASM	(N/A)	(N/A)	13.3	209.2	8.8	17.9	133.6	960.4	852.7	1,797.7	222.8	1,792.5	156.4	(N/A)	(N/A)
1975	ASM	(N/A)	(N/A)	14.1	203.5	9.8	19.9	133.1	897.9	749.5	1,633.2	183.4	1,724.4	133.6	(N/A)	(N/A)
1974	ASM	(N/A)	(N/A)	13.7	182.5	9.9	19.9	123.4	697.8	601.0	1,282.4	163.7	1,481.8	110.7	(N/A)	(N/A)
1973	ASM	(N/A)	(N/A)	13.3	164.6	9.7	19.5	111.8	463.0	416.0	884.0	67.9	1,364.0	63.1	(N/A)	(N/A)
1972	Census	48	39	13.3	152.0	9.6	18.9	102.6	455.6	365.5	823.2	61.5	1,302.0	60.4	65	65
1971	ASM	(N/A)	(N/A)	13.7	142.4	9.9	19.6	96.1	360.3	313.7	675.9	45.2	1,165.4	67.3	(N/A)	(N/A)
1970	ASM	(N/A)	(N/A)	14.7	141.3	10.5	21.4	93.5	362.0	299.6	660.3	51.0	1,158.9	67.6	(N/A)	(N/A)
1969	ASM	(N/A)	(N/A)	15.9	143.0	11.2	23.0	92.6	377.9	310.2	687.9	121.6	1,233.1	64.5	(N/A)	(N/A)
1968	ASM	(N/A)	(N/A)	16.9	140.7	11.8	23.8	90.1	372.4	286.2	664.9	90.2	1,193.8	61.9	(N/A)	(N/A)
1967	Census	44	40	19.2	155.7	12.8	25.5	94.4	419.2	302.0	719.8	98.0	1,185.6	71.4	67	75
1966	ASM	(N/A)	(N/A)	19.9	154.0	13.4	27.5	97.8	467.0	319.6	782.7	81.2	(N/A)	69.2	(N/A)	(N/A)
1965	ASM	(N/A)	(N/A)	20.0	148.2	13.5	26.8	92.1	442.8	291.4	735.4	57.7	(N/A)	65.3	(N/A)	(N/A)
1964	ASM	(N/A)	(N/A)	19.9	145.3	13.8	28.1	92.3	436.0	276.2	711.6	49.4	1,083.8	66.0	(N/A)	(N/A)
1963	Census	38	37	19.7	138.2	13.5	27.6	88.1	389.2	263.6	652.1	57.5	1,046.7	64.3	66	79

(N/A) Not available.

[a] In years of Annual Survey of Manufactures (ASM), data are estimates based on a representative sample of establishments canvassed annually and may differ from results of a complete canvass of all establishments. The ASM publication shows percentage standard errors. For data prior to 1963, see 1963 Census of Manufactures, Vol. II, table 1 of industry chapter.

TABLE 12

ECONOMIC INDICATORS

(continued)

Year[a]		All Establishments: Total (number)	All Establishments: With 20 Employees or more (number)	All Employees: Number (1,000)	All Employees: Payroll (million dollars)	Production Workers: Number (1,000)	Production Workers: Hours (millions)	Production Workers: Wages (million dollars)	Value Added: Value added[b] by Manufacture (million dollars)	Value Added: Cost of[c] materials (million dollars)	Value Added: Value of[d] shipments (million dollars)	Assets and Expenditures: New[e] Capital Expenditures (million dollars)	Assets and Expenditures: Gross[e] value of fixed assets (million dollars)	Assets and Expenditures: End-of-[e] Year inventories (million dollars)	Ratios: Specialization[f] ratio (percent)	Ratios: Coverage[f] ratio (percent)
INDUSTRY 2819, INDUSTRIAL INORGANIC CHEMICALS, NEC (TOTAL)[g]																
1977	Census	557	281	79.0	1,311.9	46.5	95.3	706.2	4,283.9	4,295.7	8,519.0	458.7	3,648.6	860.4	88	78
1976	ASM	(N/A)	(N/A)	74.6	1,186.8	43.7	87.8	615.8	3,974.7	3,475.6	7,380.5	391.1	3,462.9	753.4	(N/A)	(N/A)
1975	ASM	(N/A)	(N/A)	73.7	1,061.2	43.5	85.8	555.4	3,260.5	2,844.0	6,053.4	341.8	3,200.8	685.9	(N/A)	(N/A)
1974	ASM	(N/A)	(N/A)	68.5	897.0	42.4	84.8	491.9	2,904.4	2,723.6	5,534.9	254.7	2,964.6	621.3	(N/A)	(N/A)
1973	ASM	(N/A)	(N/A)	64.6	761.7	40.1	80.1	418.9	2,334.9	1,926.2	4,233.8	176.6	2,627.6	417.4	(N/A)	(N/A)
1972	Census	383	264	63.8	704.7	39.9	80.0	392.4	2,038.2	1,804.1	3,833.3	149.0	2,563.3	384.1	89	79
INDUSTRY 2819, INDUSTRIAL INORGANIC CHEMICALS, NEC (PRIVATELY OWNED AND OPERATED ESTABLISHMENTS ONLY)																
1977	Census	547	271	49.9	813.0	31.3	64.1	476.6	2,729.2	3,648.5	6,321.0	458.7	3,648.6	860.4	88	78
1972	Census	371	252	39.7	426.5	27.0	54.6	262.2	1,260.3	1,549.4	2,800.7	149.0	2,563.3	384.1	89	79

(N/A) Not available.

[a] In years of Annual Survey of Manufactures (ASM), data are estimates based on a representative sample of establishments canvassed annually and may differ from results of a complete canvas of all establishments. The ASM publication shows percentage standard errors. This industry was newly defined for 1972 Census of Manufactures so no comparable data prior to 1972 exist.

[b] Value added for government-owned, contractor-operated plants, included in total, was estimated based upon averages reported for commercial establishments in prior years.

[c] Total data exclude government-owned materials furnished to government-owned, contractor-operated plants, and include fuels and electric energy purchased by or for these plants.

[d] Total data include a calculated value of shipments for government-owned, contractor-operated plants, comprised of adjusted value added (estimated as described in footnote 3) plus the cost of fuels and electric energy.

[e] Includes expenditures for plants under construction. Total excludes expenditures, inventories, and fixed assets of government-owned, contractor-operated plants.

[f] Ratio excludes government-owned, contractor-operated establishments because their dollar receipts were included in miscellaneous receipts. See Appendix B for discussion of calculation of specialization and coverage ratios.

[g] Includes both privately owned and operated plants and government-owned, contractor-operated plants.

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979.); and U.S. Department of Commerce, Bureau of Census, Annual Survey of Manufactures (Washington, D.C.: Government Printing Office, various years).

compounds. However, the trade deficit in inorganic acids has been mounting in recent years. The trade balance for inorganic chemicals not elsewhere classified (NEC) has fluctuated from year to year, starting with a surplus of $142 million in 1973 and continuing to a $94 million deficit in 1977. One explanation for the deficit is that imports of alumina, uranium compounds, hydrofluoric acid, sulfur, inorganic metal salts and precious metal compounds have registered large gains in recent years. Combined with rapid inflation in world markets, it is believed that this import trend acts to worsen the balance of trade in miscellaneous inorganic chemicals.

INNOVATION

It appears that the inorganic chemicals industry has experienced very little innovation in the way of new chemical substances. Most of the chemicals and compounds that are part of the industry have well established end uses. However, we believe that it is not necessarily true that past trends will be continued in the future. Although the segment has experienced limited innovation overall, within the segment there are several specialized areas in which R&D effort has been high. For example, new phosphate, boron and silicon compounds have been developed. In recent years many new theories on inorganic chemistry have emerged from university laboratories. These theories have not yet been translated into commercial innovations. but it is quite possible that they may do so in the near future. One of the areas in which commercial applications may soon appear is in rare earth salts.

SYNTHETIC HIGH POLYMERS

SYNTHETIC HIGH POLYMERS SEGMENT SUMMARY

Plastic Materials and Resins
Organic Fibers, Non-cellulosic
Synthetic Rubber

Synthetic High Polymers are chain-like macromolecules formed by the chemical linkage of smaller molecular units known as monomers. Depending upon the nature of the monomers, these compounds can assume the form of plastics, resins, fibers, or rubbers for use in the fabrication of a wide variety of industrial and consumer goods.

The basic polymers currently in use date largely from the period 1930-1960. Some important new polymers have been developed since then--polysulfore plastic by Union Carbide (1965), olefin fibers by Hercules (1962), and Anidex fibers by Rohm and Haas (1969)--but the synthetic high polymers industry is built upon polymers that were first developed a generation ago. A relatively small number of these basic polymers have large market shares. For example, in 1978 polyester accounted for almost half of domestic non-cellulosic organic fiber production. and nylon accounted for almost one-third. Forty to fifty basic plastics are available commercially, but in 1976 polyethylene accounted for 29 percent of domestic production, polyvinyl chloride accounted for 15 percent, and polypropylene accounted for almost 9 percent. In 1976 styrene-butadiene rubber constituted more than half of all U.S. synthetic rubber output.

These characteristics of synthetic high polymers--a small number of basic products that are made in very large volumes and have dominated the industry for years--lead to a market which is dominated by large plants owned by large companies. Concentration in synthetic high polymer markets is relatively high, and this is particularly true in the synthetic fibers market. In 1976 DuPont alone owned 35 percent of domestic synthetic fiber production, and the top four firms (including DuPont) owned two-thirds of domestic production. The top four synthetic rubber producers accounted for half of domestic production in 1976, and the top eight account for 72 percent. The plastics market displays the lowest degree of concentration: in 1976 the top four producers accounted for 27 percent of domestic production, and the top eight firms accounted for 38 percent.

Because of the characteristics of high polymer markets outlined above, chances seem low that a radically different generic fiber could be developed that could compete successfully with today's major fibers. Not only would finding such a fiber be difficult in this well-researched field, but the cost of building a plant with a large capacity and then establishing that new fiber in the man-made fiber market would require a large commitment of resources.

Anidex, the last generic fiber to be developed, was introduced in 1969. Rohm and Haas reputedly spent $20 million and 10 years of research to develop this product. A 1977 estimate by an industry executive was that a minimum of $50 million and 5 to 10 years of development would be required to commercialize a new generic product for broad-based market application.

Even though the roster of basic polymers is quite stable, a constant stream of new products emerges from the synthetic high polymer industry. In recent years there seems to have been much innovation in the area of copolymers. Copolymers differ from other polymers in that the polymers are built from two or more different types of monomers rather than from one type of monomer. The same building blocks are used in copolymers as in polymers--they are simply put together in different ways.

The production of copolymers is not the only way in which the synthetic high polymer industry introduces new products. By the use of additives which affect color, flexibility. stability, tensile strength, electrical conductivity, and dozens of other properties, and by the use of different methods of processing the basic materials, manufacturers are able to produce literally thousands of different formulations, custom-tailored to specific end-uses. For example, in 1977, Hercules, Inc. the largest producer of polypropylene at that time. had more than 150 polypropylene products available. Most of the additives which are used to produce these products are covered in another segment--Organic Chemicals. NEC.

Plastics and Resins

PLASTICS MATERIALS AND RESINS

DESCRIPTION

Plastics and resin materials are high molecular weight polymers or macromolecules which at some stage in their manufacture, exist in such physical condition that they can be shaped or otherwise processed by the application of heat and pressure. The terms "plastic," "resin," and "polymer," are often used interchangeably. Strictly speaking, a "plastic" is a relatively tough resin. with a molecular weight between 10,000 and 1,000,000, that can be formed into solid shapes with good mechanical properties under the influence of heat and pressure. The term "resin" is used for the nonstructural polymers in protective coatings, adhesives. and binders. Commonly, a processed polymer is called a plastic and an unconverted polymer, a resin. "Latexes" are dispersions of resins in water.

There are about 40 to 50 basic plastics and resins available commercially.[1] These basic materials have thousands of individual compounds, each with its distinct properties depending on the molecular weight of the resin and the types and amounts of the additives present. Common characteristics of plastics which are considered in production are strength, dimensional stability, toughness, and other desirable mechanical properties. Other characteristics are weight; ease of fabrication; resistance to wear, water, and chemical attack; and color.

Plastics and resin materials are categorized generally into thermosetting and thermoplastic types. Thermosetting materials harden with a change in composition in the final treatment so that their final state is substantially infusible and insoluble. That is, they cannot again be softened by heat or solvents. Thermosetting materials comprised 20.6 percent[2] of total U.S. plastics and resins production in 1977. The most important products in this category are phenolic, amino , polyester, and alkyd resins.

Thermoplastic materials have final states that can be repeatedly softened by heating and hardened by cooling. In 1977 thermoplastic materials accounted for 79.4 percent[3] of total U.S. plastics and resins production. The most important products in this category are polyethylene, vinyl resins, and styrene-type materials.

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[1] Edward J.Taylor, "Plastics and Resin Materials," Synthetic Organic Chemicals, 1977 (Washington, D.C.: U.S. International Trade Commission, 1977), p. 220.

[2] Ibid., p. 220, calculated from data presented in article.

[3] Ibid., calculated from data presented in article.

HISTORY

The first commercial plastic was cellulose nitrate (celluloid), patented in 1870. Four decades passed before a predecessor company of Union Carbide introduced the phenolics (Bakelite) in 1909. By the 1930s more than a dozen plastics were either on the market or well along in development. World War II created a heavy demand for materials of all kinds. Polymer research and production accelerated markedly, and established the technological base for the industry.

Polyethylene is the largest-volume plastic in both the U.S. and the world. It was discovered during the period 1932 to 1935 by Imperial Chemical Industries, Ltd., in the course of a research program on the effects of very high pressure on chemical reactions. Although the initial discovery was accidental. it became evident that polyethylene was the ideal material for shielding microwave cable in military radar equipment. The British work on radar was a top priority project as World War II drew near and sharply spurred the development of polyethylene.

Although the major classes of commercial plastics and resins date largely from World War II and earlier, important new polymers have been recently discovered. Some examples are:

- General Electric's Lexan polycarbonate in 1960;
- DuPont's Delrin polyacetal (polyformaldehyde) in 1960; and
- Union Carbide's polysulfone in 1965.

ENGINEERING PROCESS

Plastic materials and synthetic resins are either (1) formed by the polymerization or polycondensation of organic intermediates or (2) chemically modified from such natural polymers as cellulose. Common monomers are ethylene, propylene, styrene, and vinyl and acrylic compounds.

In polycondensation, two or more different molecules (or monomers) are reacted to form large molecules of high molecular weight, usually with the elimination of a small molecule such as water or methanol. Examples are the condensation of urea or phenol with formaldehyde. When more than one type of monomer is being polymerized, the material formed is called a copolymer.

Polymerization of vinyl chloride, as an example, may be carried out by any of several methods: suspension, emulsion, solution, or mass. Suspending agents are needed for suspension polymerization, emulsifying agents are needed for the emulsion method. The latter also requires coagulating aids to bring the polymer out of emulsion. Usually two or more catalysts are used.

The basic polymer is seldom used alone in plastics. Polyvinyl chloride requires a thermal stabilizer to prevent loss of hydrogen chloride in any processing step at temperatures above 100°C. Flexible polyvinyl chloride films and foams require 20 to 40 percent of a plasticizer (organic chemical that improves workability during fabrication). Flow agents may be included to facilitate heat fabrication. Other additives may include colorants, solid fillers to improve properties and reduce costs, and rubbers to improve low temperature properties. Plastics in general may contain such additional additives as antioxidants, carbon black to stabilize against degradation by light, delusterants, self-extinguishing agents, agents that control surface properties, and so on.

RAW MATERIALS

Petroleum and natural gas are the basic raw materials of the plastics materials and resins industry. For example, naphtha, derived from crude oil, is the source of benzene. It is modified by chemical processes and converted into resins such as alkyds, acrylonitrile-butadiene-styrene, styrene-acrylonitile, polystyrene, phenolics, polycarbonates, and silicones.

Natural gas is the main source of ethylene and propylene, which are basic to the production of polyethylene, polyvinyl chloride, polyvinyl acetate, polypropylene, acrylics, and other resins. Liquefied refinery gases, obtained from crude oil, serve as another source of ethylene, propylene and butylene. Any restrictions on the supply of benzene, ethylene or propylene are bound to limit the availability of synthetic resins.

As mentioned earlier, the base polymer is seldom used alone in plastics. The most common additives are plasticizers, fillers, antioxidants, ultraviolet radiation absorbers. stabilizers, flame retardants, and colorants.

USES

The plastics materials and resins industry (SIC 2821) produces material for sale to the plastic products industry (SIC 3079) and other industries for molding, extruding, casting, fabricating and finishing into components or parts for such products as furniture. automobiles and appliances.

The versatility of plastics materials is responsible for much of their growth in competition with metal. wood, paper, and glass. Many of these materials have been gradually replaced by plastics which offer improved properties, often at lower cost. Plastics can be produced with the physical and chemical properties required to fulfill special product needs and are used by most industries because of their ready adaptability to high output processing methods.

It appears that markets for plastics and resins are so diverse that overall demand is not appreciably influenced by single factors such as defense spending, shifts in fashion, or changes in the composition of the population. Three of the principal markets for plastic materials are packaging, building/construction, and automotive applications. Table 1 provides information on the consumption of the major types of plastics in 1976 and their major uses.

Packaging represents a highly diversified market for plastics. Packaging is the single most important use for thermoplastic resins, representing in 1976 about 30 percent[4] of all the thermoplastic resins consumed. Packaging materials include both rigid and flexible plastic items such as shrink wrap, blister containers, bottles, disposable cups, boxes, and trays. Plastics material constituted about 10 percent[5] of all material used in packaging in 1976. The growth of plastics in packaging has been at the expense of both traditional materials (glass, paper products, and nonferrous metals) and older plastics (e.g., cellulosic plastics).

The preference for newer plastics materials over other materials is due primarily to cost and performance factors. For example, plastics may be formed into a greater variety of shapes, and at lower temperatures and lower energy requirements than glass or metal. Also, plastics are typically lighter than glass or metal. which results in lower shipping costs.

Major synthetic plastics used in construction include pipe, siding, and insulation. Approximately 40 percent[6] of the thermosetting resins are consumed in this market. Insulation applications have made substantial gains as a result of the energy crisis. Polyurethane foam and polystyrene foam are two of the principal materials used in insulation. Other important plastics applications in the building and construction sector are glazing, panels, ducts, and tanks. In 1976, plastic products accounted for about five percent[7] of all the materials used in building and construction. Growth is projected because plastics are increasingly being accepted by building contractors, and because building codes are being rewritten to accommodate them.

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[4] Edward J. Taylor, "Synthetic Resins and Plastics Materials," Synthetic Organic Chemicals, 1977 (Washington, D.C.: U.S. International Trade Commission, 1977), p. 212.

[5] Ibid., p. 212.

[6] Ibid., p. 211.

[7] Ibid., p. 212.

TABLE 1

CONSUMPTION OF MAJOR PLASTICS MATERIALS AND SYNTHETIC RESINS BY END USE: 1976

(millions of pounds)

	Packaging	Construction	Housewares[a]	Electric and Electronic	Transportation	Paints	Toys	Furniture	Appliances	Other domestic
Polyethylene										
Low-density[b]	2,515	200	1,170	340	--	--	110	25	10	775
High-density	1,320	280	350	--	20	--	150	--	10	650
	3,835	480	1,520	340	20	--	260	25	10	1,425
Vinyl										
Chloride	375	2,200	100	350	285	80	75	210	45	455
Other	225	--	--	--	--	40	--	15	--	580
	600	2,200	100	350	285	120	75	225	45	1,035
Styrene										
Polystyrene										
Solid	875	110	385	220	--	--	340	100	155	75
Foam	280	--	120	--	--	--	--	--	--	145
	1,155	110	505	220	--	--	340	100	155	220
ABS and SAN	35	250	20	70	170	--	90	10	130	355
Other	--	--	--	--	--	25	--	--	--	535
	1,190	360	525	290	170	25	430	110	285	1,110
Polypropylene	430	15	130	85	365	--	70	30	90	945
Polyurethane foam	45	265	--	--	485	--	--	510	80	240
Phenolic	10	610	50	200	50	25	--	60	85	190
Polyester	--	185	--	55	160	10	--	20	35	425
Amino	15	705	35	35	--	75	--	15	--	320
Alkyd	--	--	--	--	--	650	--	--	--	40
Acrylic	--	135	--	--	75	100	--	--	5	525
Cellophane	200	--	--	--	--	--	--	--	--	10
Courmarone-indene[c]	40	30	--	--	--	35	--	--	--	195
Epoxies	--	15	--	15	15	90	--	--	5	70
Cellulosics	45	5	--	5	15	--	5	--	--	80
Polyamides	--	--	--	25	45	--	--	--	10	45
Other[d]	165	40	10	70	70	--	5	--	50	50
TOTAL	6,575	5,045	2,370	1,470	1,755	1,130	845	995	700	6,705

[a] Includes data for film consumed in household and institutional bags and wraps, wallcoverings other than paints, garden hose, and dinnerware.

[b] Includes data for ethylene copolymers.

[c] Includes data for petroleum hydrocarbon resins.

[d] Includes engineering thermoplastics, silicones, fluoroplastics, and others.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, N.J.: Charles Kline & Co., 1977), p. 91.

Although plastics are used in all forms of transportation, the automobile is the largest end use for plastics in the transportation industry. Weight reduction for improved fuel economy has been an important stimulant for the growing use for plastics in automobiles. The average 1977 automobile was estimated to contain 166 pounds of plastics as compared with 20 pounds in the typical 1960 automobile.[8/] It has been forecast that the typical 1985 automobile will contain 350 to 500 pounds of plastics.[9/]

Between 1966 and 1976, the production of synthetic resins and plastics materials increased at an average rate of 8 percent per year,[10/] representing one of the highest growth rates within the chemical industry. Continued high rates of growth are likely, both through continued gains of market shares in existing products and through the development of new products.

PRODUCTION

Table 2 provides information on the plastics and resins industry including numbers of employees, value added by manufacture, and value of shipments. U.S. production volumes of plastics and resins are shown in Table 3.

Shipments grew at an average rate of 12.4 percent a year between 1967 and 1977 and in 1977 represented 14 percent of the shipments of the entire chemical industry.[11/] Between 1948 and 1976 physical production of plastics and resins other than cellophane increased more than 15 times, for an average annual growth of 10 percent.[12/]

INDUSTRY STRUCTURE

The plastics and resins industry is somewhat concentrated since the production of polymers requires a high capital investment. In 1976, the top four companies accounted for an estimated 27 percent of shipments; the top

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[8/] Ibid., p. 213.

[9/] Ibid.

[10/] Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 91.

[11/] Ibid., p. 85.

[12/] Ibid.

TABLE 2

PLASTICS AND RESINS INDUSTRY STATISTICS

Year	Number of Employees (1,000)	Number of Production Workers (1,000)	Value Added by Manufacture (million dollars)	Value of Shipments (million dollars)
1977	57.4	36.9	4,015.3	10,622.1
1976	56.2	36.4	3,524.4	9,201.9
1975	54.3	34.0	2,770.5	7,043.1
1974	57.7	37.6	3,640.1	7,773.0
1973	54.4	35.0	2,490.0	5,159.4
1972	54.8	35.0	2.160.5	4,478.2

Source: U.S. Department of Commerce, Bureau of the Census. 1977 Census of Manufactures. (Washington, D.C.: Government Printing Office, 1979).

TABLE 3

PLASTICS MATERIALS AND RESINS PRODUCTION

(millions of pounds

	1966	1974	1975	1976
Polyethylene				
Low-density[a]	2,648	6,027	4,889	5,611
High-density	910	2,799	2,594	3,113
Total	3,558	8,826	7,483	8,774
Vinyl resins				
Polyvinyl chloride and copolymers	2,164	4,744	3,695	4,545
Polyvinyl acetate	336	543	526	617
Polyvinyl alcohol	38	141	118	126
Other	132	241	197	265
Total	2,670	5,669	4,536	5,553
Styrene resins				
ABS and SAN[b]	362	1,009	791	1,003
Other	2,032	4,051	3,086	3,740
Total	2,385	5,060	3,877	4,743
Urethane chemicals[d]				
Polyurethane and diisocyanate resins	72	193	119	126
Polyether and polyester polyols	--	1,112	932	1,346
Total	72	1,305	1,051	1,472
Polypropylene[c]	554	2,249	1,903	2,551
Phenolics	1,047	1,578	1,275	1,305
Amino	718	1,236	1,057	1,229
Polyesters-saturated and unsaturated	470	944	879	973
Acrylics[c]	d	890	778	888
Alkyds	666	726	674	705
Engineering plastics[g]	d	398	266	f
Cellophane[e]	395	335	300	325
Petroleum hydrocarbons and coumarone-indene resins[h]	334	407	360	306
Epoxies--unmodified	140	270	183	203
Polyamides[c]	93	221	144	155
Celluosics	116	224	157	f
Rosin modifications	131	123	64	64
Other	561	1,228	128	678
Total	13,910	31,689	25,115	29,924

[a] Includes ethylene copolymers.

[b] 1976 figures are only for ABS.

[c] Excludes resins for man-made fibers.

[d] Excludes isocyanic acids which are found in cylic intermediates.

[e] Estimates.

[f] Included in other.

[g] Includes such grades as acetals, polycarbonates, polyimide, polyphenylene sulfide, polysulfone and polyphenylene oxide.

[h] 1976 data excludes coumarone-indene resins.

Source: Mary K. Meegan, ed., *Kline Guide to the Chemical Industry*, (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 91.

eight, 38 percent. Table 4 shows the 30 largest producers, along with their 1976 estimated sales in domestically produced synthetic resins. The 30 leading producers accounted for about 72 percent of total shipments.[13] In 1977 there were 337 establishments with 20 or more employees in the industry.[14]

Despite the concentration, a competitive environment exists. There are a large number of producers serving the same markets and competition from different products for the same applications.

PRICES

Table 5 gives indices of average manufacturers' prices for selected plastics. Between 1967 and 1972 prices generally fell. This was partially a result of the low-volume specialties developing into high-volume commodities, with consequent lower costs of production due to economies of scale. The declines also reflect expanding production capacities from both old and new producers because of the high growth attraction to the industry. This overcapacity situation has led to frequent price cutting.

From 1972 through 1975 overall prices increased by 80 percent, consistent with large price increases for most chemicals. Plastics prices in 1976 were only four percent higher than 1975 levels. Price increases for plastics over the 1967 to 1977 period have generally been significantly lower than price increases for iron and steel, lumber, and plywood. Price increases for nonferrous metals and pulp and paper were comparable to or slightly less than plastics' price increases.[15]

FOREIGN TRADE

Table 6 shows imports, exports, and the trade balance in plastics and resins. As can be seen, the trade balance has generally increased over the 1968 to 1977 period.

In 1977 exports accounted for 16.6 percent of total U.S. shipments of plastics materials. Thermoplastic commodity resins accounted for 45

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[13] Ibid., p. 93.

[14] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures. (Washington, D.C.: Government Printing Office, 1979).

[15] U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

TABLE 4

MAJOR U.S. PRODUCERS OF PLASTICS AND RESINS: 1976

Rank	Company	Domestically Produced Plastics Materials and Resins ($ million)	Total Chemical Sales ($ million)	Plastics Materials and Resins Percent of Total Chemical Sales (%)	Total Sales[a] ($ million)	Plastics Materials and Resins Percent of Total Sales (%)
1	Dow Chemical	900	4,320	20.8	5,652	15.9
2	DuPont	800	7,300	11.0	8,361	9.6
3	Monsanto	600	3,577	16.8	4,270	14.1
4	Union Carbide	550	4,000	13.8	6,346	8.7
5	Reichhold	345	490	70.4	585	60.0
6	Rohm and Haas	300	825	36.4	1,053	28.5
7	General Electric	275	375	73.3	15,697	1.8
8	ARCO Polymer[c]	250	826	30.3	8,462	3.0
8	Borg-Warner	250	350	71.4	1,862	13.4
10	Exxon	225	3,238	6.9	48,631	0.5
10	Hercules	225	1,375	16.4	1,596	14.1
12	Allied Chemical	200	1,738	11.5	2,630	7.6
12	Amoco	200	1,432[b]	14.0	11,532	1.7
14	B.F. Goodrich	175	450	38.9	1,996	8.8
14	W.R. Grace[d]	175	1,385	12.6	3,615	4.8
14	Phillips Petroleum	175	1,230	14.2	5,698	14.2
17	Hooker (Occidental Petroleum)	160	1,536	10.4	5,534	2.9
18	Celanese	150	1,855	8.1	2,123	7.1
18	Diamond Shamrock	150	813	18.5	1,357	11.1
20	Gulf Oil	150	1,062	14.1	16,451	0.9
20	Shell Chemical	150	1,574	9.5	9,230	1.6
22	Borden	135	500	27.0	3,381	4.0
22	USI (National Distillers)	135	340	39.7	1,504	9.0
24	Chemplex	125				
24	Eastman Kodak	125	1,247	10.0	5,438	2.3
26	Foster Grant	110				
26	Northern Petrochemical	110	--	--	--	--
26	Soltex (Solvay)	110	--	--	--	--
29	American Cyanamid	100	1,096	9.1	2,094	4.8
29	Dart Industries	100	170	58.8	1,476	6.8
--	Others	3,105	--	--	--	--
	Total	$10,560	--	--	--	--

[a] Sales exclude value of collected exise taxes, equity interest, dividends, royalties, fees and other non-operating income.

[b] Includes fabricated plastics.

[c] Sales figures are for Atlantic Richfield.

[d] Includes $252 million in sales by its majority-owned subsidiary, Chemed Corporation.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), pp. 7 and 94.

TABLE 5

INDICES OF AVERAGE MANUFACTURERS' PRICES OF PLASTICS AND RESINS: 1967-1976

(1967=100)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Thermoplastics										
Polyethylene										
Low-density[a]	100.0	101.4	82.3	85.0	85.7	83.0	93.3	153.3	173.3	199.7
High-density	100.0	91.7	89.9	83.4	71.0	69.2	82.4	123.5	152.9	167.1
Vinyl resins										
Polyvinyl chloride[b]	100.0	89.2	87.3	86.0	85.4	82.8	93.8	143.8	150.0	164.7
Polyvinyl acetate	100.0	87.0	90.8	79.5	81.8	79.8	82.8	110.3	120.7	135.4
Styrene resins										
ABS and SAN	100.0	86.3	84.5	89.9	86.0	86.3	87.8	118.2	124.2	--
Other	100.0	94.6	93.5	92.9	88.6	85.9	111.1	177.8	177.8	--
Polypropylene	100.0	97.7	101.4	92.5	81.8	73.8	81.0	114.3	119.0	131.9
Total thermoplastics[c]	100.0	88.3	87.8	85.9	84.5	83.1	90.5	137.6	152.4	157.0
Thermosetting										
Phenolics	100.0	94.9	93.2	84.3	88.1	89.8	79.4	149.9	166.7	162.3
Amino	100.0	83.2	80.6	74.1	76.7	87.1	52.1	82.6	95.7	100.2
Polyesters	100.0	98.9	97.5	83.9	81.0	67.4	82.1	142.9	107.1	154.0
Alkyds	100.0	94.5	100.4	100.4	101.1	101.5	111.1	170.4	163.0	155.8
Epoxies	100.0	100.0	99.4	88.3	92.0	88.0	102.0	121.6	133.3	150.7
Total thermosetting[c]	100.0	100.8	99.6	92.2	94.2	90.3	80.8	138.5	150.0	153.8
Total[c]	100.0	90.6	89.2	86.4	85.2	83.4	90.9	136.4	150.0	159.1

[a] Includes ethylene copolymers.

[b] Includes vinyl chloride copolymers.

[c] Includes products now shown separately.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles Kline and Co., 1977), p. 95.

TABLE 6

FOREIGN TRADE OF PLASTIC AND RESINS

(millions of dollars)

Year	Imports	Exports	Trade Balance
1968	93	590	497
1969	99	590	491
1970	123	653	530
1971	133	657	524
1972	177	696	519
1973	207	1,028	821
1974	357	1,618	1,261
1975	247	1,173	926
1976	340	1,672	1,332
1977	415	1,768	1,353

Sources: For 1968-1976, Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed.. Fairfield NJ: Charles Kline and Co., 1977), p. 95; for 1977, U.S. Department of Commerce, U.S. Industrial Outlook 1978, (Washington, D.C.: Government Printing Office, 1978).

percent in the same year.[16] Large U.S. exports of plastics, particularly the commodity resins, are indicative of the inability of the manufacturers of developing countries to keep pace with U.S. production. Living standards in these countries are creating a considerable need for raw materials which can be satisfied only by other than traditional natural sources.

Canada was the leading market for U.S. exports of plastics in 1977, as it had been during the previous decade. Other important U.S. markets in the Western Hemisphere during 1977 included: Brazil, Colombia. Ecuador, Guatemala,

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[16] Edward J. Taylor, "Synthetic Resins and Plastics Materials," p. 212.

Mexico, and Venezuela--nations whose fabrication demands have outpaced their local plastics production capabilities. The major Asian markets in 1977 included Hong Kong, Japan, Korea. New Zealand the Philippines, Singapore, and Taiwan. The leading markets in Europe were all developed nations--Belgium, the Netherlands, France, and West Germany. A significant share of these exports are believed to represent shipments by U.S. producers to their own European subsidiaries.

U.S. plastics producers face competition with many efficient producers throughout the world. Capacity is also rising sharply in countries outside the Common Market, and the developing countries are expected to show the fastest growth in the production and consumption of synthetic resins. As markets expand, substantial investments are expected in these regions. For example, the buildup of capacity in the Middle East with access to inexpensive raw materials makes the Middle East a very promising future exporter.

Except for 1974, imports of plastic materials and resins have not exceeded one percent of consumption in any year during the 1950 to 1977 period.17/ Traditionally, the capital-intensive, technology-oriented manufacture of plastics has given the United States a competitive edge over its foreign competition, but that advantage appears to be diminishing.

The leading sources of imports in 1977 included Canada, France, Japan, the United Kingdom. and West Germany, together accounting for three-fourths of the volume of plastics imports in that year, and two-thirds in 1976. Since most foreign plastics do not compete with domestic plastics in the U.S. market, imports are usually sought for one of three reasons: (1) a shortage of a particular resin exists in the United States; (2) the imported plastic is a new product not yet made domestically; or (3) foreign firms are supplying their U.S. affiliates or subsidiaries to make up for a short-fall for a given plastic or resin.

The pattern of U.S. imports of plastics materials is not expected to change signifcantly until at least the mid-1980s.18/ At that time, the nations of the Middle East are expected to attain a capacity for plastics which will allow them substantial export capabilities.

17/ Ibid., p. 214.

18/ Ibid.

INNOVATION

The plastics and resins segment seems to have been one of the fastest growing segments within the chemical industry. The impetus behind this growth has been the versatility of plastics, displacing other materials in many uses while offering superior performance at lower costs. Plastics can be formulated with specific physical, electrical, and chemical properties that can meet an endless series of requirements.

About 40 to 50 basic plastics and resins are manufactured. For most of these, the ability of producers to vary molecular weights, copolymers, plasticizers, colorants and other additives--together with their ability to vary processing parameters such as temperature, time and pressure--has led to production of thousands of different formulations, custom-tailored to specific end uses. Polypropylene products illustrate this point. In 1977 Hercules, Inc., the largest producer of polypropylene at that time, had more than 150 polypropylene products available.[19]

Review of a plastics buyers' guide[20] further illustrates this point. For extension grade acrylonitrile-butadiene-styrene (ABS), one of a number of grades available, five suppliers were listed (Abtec, Borg-Warner, Mobil, Monsanto, and USS Chemicals) in a recent buyers' guide. Readily available product information (advertisements) for Abtec Chemical Company and USS Chemicals were reviewed. Abtec listed seven extension grade products with different impact strengths and flame-retardancy characteristics. USS Chemicals listed five extension grade ABS products with various impact strengths, tensile strengths. and heat deflection data and also provided qualitative information for each product. This review suggests the large numbers of plastics materials available and the ability of the chemists to design chemicals for specific requirements.

Innovation will continue to bring new products to the plastics materials and resins industry. It seems unlikely that any new polymers discovered will combine the broad utility and low cost to rival plastics such as polyethylene, polypropylene, or polystyrene.[21] More likely is the advent of new, specialized materials such as polycarbonates, polyacetals. and others which have been commercialized in the past several decades. Additionally, we believe new products within existing types of plastics materials and resins will likely continue to be produced at a high rate.

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[19] "Polypropylene: R&D is the Key," Chemical Marketing Reporter, March 14, 1977.

[20] Modern Plastics Encyclopedia, McGraw Hill, October 1976, Vol. 56.

[21] American Chemical Society, Chemistry in the Economy. a study supported in part by the National Science Foundation, 1973, p. 82.

Organic Fibers, Non-Cellulosic

ORGANIC FIBERS, NON-CELLULOSIC

DESCRIPTION

Just like plastics, non-cellulosic organic fibers are polymers. These fibers are also known as "synthetic fibers".

Table 1 lists the major synthetic fibers, the monomers or polymers involved, and the first commercial U.S. producer. As can be seen, there are nine generic types of synthetic fibers in commercial production in the U.S. However, within each generic type of synthetic fiber, there are a great many different variations (up to several thousand in some cases). each individually tailored to meet the requirements of a specific end use.

Synthetic fibers have great versatility and can be tailored for improved washability, durability, tensile strength, and resistance to soiling and shrinking. These advantages have allowed them to gradually replace natural fibers in many applications.

HISTORY

After seven years of effort, in 1935 scientists at DuPont successfully combined hexamethylene diamine and adipic acid to form a fiber which was subsequently named Nylon. This began the non-cellulosic organic fiber industry.

Other synthetic fibers followed nylon in short order. I.G. Farbenindustrie in Germany sold a slightly different nylon commercially in 1939 (Perlon). In England, Calico Printers Association produced the first polyester fiber (Terylene) on a pilot-plant scale in 1948. Union Carbide began selling an acrylonitrile-vinyl chloride fiber (Dynel) in 1949, and DuPont followed with an acrylonitrile fiber (Orlon) in 1950. DuPont bought American rights to Calico's polyester in 1946, produced experimental quantities in 1950. and began full-scale commercial production (of Dacron) in the U.S. in 1953. DuPont added a urethane fiber (Spandex) in 1959, and Hercules produced textile-grade polypropylene fibers (Herculon) in 1961.

The Textile Products Identification Act was passed to bring order to the naming of man-made fibers.[1] The Act named "manufactured" fibers generically and required manufacturers to use these generic names on textiles.

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[1] "Man-made fibers" in this paper means both cellulosic and non-cellulosic organic fibers unless otherwise noted.

TABLE 1

NON-CELLULOSIC ORGANIC FIBERS

Generic Name	Monomer or Polymer[a]	First Commercial U.S. Producer	Year
Nylon	Polyamide	E.I. duPont de Nemours & Co.,	1939
Vinyon	85% vinyl chloride	American Viscose Corp. (now FMC Corp.), and Union Carbide Corp.	1939
Saran	Vinylidene chloride	Firestone Plastics Co. (now Firestone Synthetic Fibers and Textiles Co.)	1942
Modacrylic	35-85% Acrylonitrile	Union Carbide Corp.	1949
Acrylic	85% Acrylonitrile	E.I. duPont de Nemours & Co.	1950
Polyester	Ester of dihydric alcohol and terephthalic acid	E.I. duPont de Nemours & Co.	1953
Spandex	Urethane	E.I. du Pont de Nemours & Co.	1959
Olefin[b]	Ethylene. propylene, or other olefin	Hercules Powder Company (now Hercules, Incorporated)	1962
Anidex	Monohydric alcohol/ acrylic acid ester	Rohm and Haas Company	1969

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[a] Indicative only, as some definitions are more complex than shown.

[b] Hercules produced olefin monofilaments for specialized use in 1949, but the first production of textile grade monofilament occurred in 1961. In addition to the above fibers, there are three others, azlon, nytrile, and vinyl, that are no longer produced commercially in the U.S., and lastrile, that has not ever been produced commercially.

Source: American Chemical Society, Chemistry in the Economy, a study supported in part by the National Science Foundation, 1973.

ENGINEERING PROCESS

The process of producing a polymer is called polymerization. The polymerization processes--batch and continuous--used for producing the various non-cellulosic organic fibers are basically similar. In the batch process, the polymer is produced in batches, then sent into a spinning process. In the continuous process, the polymer is made continuously and spun continuously. To make the polyester polymer, dimethyl terephthalate is reacted with ethylene glycol at a temperature between 150-210°C in the presence of a catalyst. A monomer (dihydroxydiethyl terephthalate) is created and transferred to a polymerization autoclave, where the temperature is raised to about 280°C.[2]

When the desired viscosity is reached, the polymer is extruded, cooled and formed into chips. All moisture is removed to prevent irregularities. Polymer chips are melted under high temperatures (260-270°C) into a syrup-like solution which is then forced through the tiny holes of a spinneret or jet. This forms the fiber (filament).

Filaments can be produced in various diameters. Monofilaments usually have relatively large diameters and are most frequently used for non-textile applications. Textile multifilament yarns consist of several small-diameter filaments twisted together and are the most widely used type of yarn. The size and number of strands used. as well as the amount of twist, can be varied to form yarns of various sizes. The surface texture and softness which this yarn gives to fabrics makes it appropriate for many ready-to-wear and home furnishings uses. Multifilament yarn can also be textured to provide yarn with more "natural" properties.

Filaments are also cut into short wavy strands varying in length from one to five inches. These cut strands, called staple, are spun into soft, springy yarns which are used especially in rugs, carpets, sweaters, and socks.

As the filament leaves the spinneret, it is cooled and stretched to three or four times its original length. This provides the filament strands with greater strength and elasticity. since random molecules are all drawn into a parallel formation. When monofilaments are wound. the process is complete.

Staple fiber undergoes several additional steps after being stretched. Compression boxes force the fiber to buckle back on itself like an accordion, 9 to 15 crimps per inch. Crimping holds the fiber together, giving it coherence during the yarn spinning stage. The crimped fiber is dried at 100-150°F to set the crimp. The crimped and heat-set fiber is cut into lengths determined by its eventual end use. The material, called staple at this point, is baled and the process is complete.

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[2] American Fabrics Magazine, Encyclopedia of Textiles (2nd ed., Englewood Cliffs, New Jersey: Prentice-Hall, Inc. 1973), p. 31.

RAW MATERIALS

The production of organic fibers depends heavily on petroleum as a source for the basic chemicals required. The production of saran fibers provides a good example of this dependence. Ethylene is obtained from petroleum by cracking, and chlorine is extracted from salt water by electrolysis. Chlorine and ethylene combine to form trichloroethane which is polymerized into polyvinylidene chloride.

USES

In 1975 consumer goods led industrial goods as a market for man-made fibers by about three to one (see Table 2). Consumer goods include apparel; home furnishings (mainly bedroom and bathroom supplies, floor coverings, upholstery, and draperies); and toys, luggage, hospital supplies, and shoes. Tires dominate the industrial market Reinforced plastics and a diverse array of other products (hose, rope. belting, sewing thread, etc.) comprise the rest of the industrial market.

Wool and cotton have been the most widely used fibers up to recent times. Man-made fibers have been increasing their share of the market and in 1968, surpassed natural fibers in U.S. consumption.[3] Table 2 shows how man-made fibers have increased their market shares in nearly every consumer and industrial market between 1970 and 1975. Table 3 provides some recent general market share information. Man-made fibers occupy approximately 75 percent of the market at present.

Man-made fibers succeeded so dramatically and changed clothing, home furnishings, and industrial textiles to such a large extent because they are long lasting and easy to care for. Non-cellulosic fibers generally soften at high temperatures, and fabrics may therefore be heat-treated to set pleats, develop shape retention, or receive embossed designs. Non-cellulosic fibers are generally abrasion resistant, which allows them to withstand surface wear and rubbing. Most of the fibers are resilient springing back when crushed. They are relatively non-absorbent and quick drying. The smooth, non-porous surfaces of most of these fibers do not allow dirt and grime to become imbedded. Most non-cellulosic fibers are non-allergenic and are not affected by moths or mildew.

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[3] American Chemical Society, Chemistry in the Economy, a study supported in part by the National Science Foundation, 1973, p. 89.

TABLE 2

U.S. MILL CONSUMPTION OF MAN-MADE FIBERS BY END USE: 1970 AND 1975

	Million lbs. a/		% Man-Made to all fibers	
	1970	1975	1970	1975
HOME FURNISHINGS				
Carpets and rugs	1,098	1,591	87.7	98.1
Draperies and upholstery	320	317	54.4	57.8
Sheets	109	196	21.7	41.7
Blankets	91	103	75.8	88.0
Curtains	25	44	56.8	75.9
Bedspreads and quilts	27	34	18.4	31.4
Towels	1	14	1.0	5.1
Other	1.110	1,617	85.4	96.6
Subtotal	2.781	3,916	64.9	80.2
APPAREL				
Men's suits, slacks and coats	299	509	48.2	59.5
Women's dresses	406	405	71.2	80.5
Women's suits, slacks and coats	230	385	49.2	64.7
Shirts	193	248	54.4	57.8
Women's blouses	90	221	52.9	75.9
Women's under- and nightwear	179	153	58.9	73.2
Apparel linings	182	115	64.3	60.2
Uniforms and work clothes	82	109	35.5	46.0
Anklets and socks	65	86	53.3	71.7
Sweaters	76	78	70.4	77.2
Men's under- and nightwear	33	61	12.4	22.0
Robes and loungewear	47	60	60.2	73.4
Hosiery	66	52	100.0	100.0
Swimwear and other recreational wear	30	31	33.7	36.9
Other	177	177	59.4	54.0
Subtotal	2.155	2,690	53.5	64.5
INDUSTRIAL AND OTHER CONSUMER GOODS				
Tires	558	510	100.0	100.0
Reinforced plastics	245	371	91.4	93.7
Retail piece goods	200	410	58.1	73.9
Medical, surgical and sanitary products	83	129	48.3	60.8
Rope, cordage, and tape	77	128	57.4	78.5
Coated fabrics	19	77	19.8	55.4
Sewing thread	25	45	26.0	39.1
Other	384	577	50.6	67.6
Subtotal	1,591	2.247	65.9	77.0
Total	6,527	8,853	60.5	73.3

a/ Includes data for glass fibers.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles H. Kline & Co., 1977), p. 100.

TABLE 3

MILL FIBER CONSUMPTION
(millions of pounds)

Fiber	1975	1976	1977	1978	1979[a]	1980[a]
Wool	110.0	121.7	108.1	117.1	108.8	104.0
Cotton	3,206.7	3,413.9	3,182.6	3,043.0	3,100.0	3,095.0
Man-made	7,416.6	8,052.5	8,900.2	9,338.3	9,808.0	9,350.0
Total	10,553.6	11,588.1	12.190.9	12,498.4	13,016.0	12,549.0

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[a] Estimate.

Source: Textile World, January 1980, p. 62.

No fiber is considered an all-purpose fiber able to meet all the varied requirements of apparel, home furnishings, and other textile uses. The success of man-made fibers has been based largely on scientists' ability to adapt man-made fibers to an ever-increasing variety of end uses.

Polyester is the largest-volume man-made fiber produced (see Table 4). Much of polyester's growth has been in blends with cotton for permanent-press fabrics. Polyester is also used in sheets, curtains, carpets, and towels. Fiberfill, a short-length polyester fiber, is rapidly replacing cotton and down as a filling material for pillows, comforters, and furniture. Polyester's major industrial application is in tires where it is used as the body cord of belted-bias tires.

Nylon was used in ladies' hosiery at the end of World War II and soon replaced silk and rayon in this application. Currently, carpets and rugs are the largest outlet for nylon fibers, accounting for 56 percent of nylon's 1975 domestic shipments.[4] Flat knit fabrics and yarn for hosiery are two of nylon's major apparel uses. Tire cord is the major industrial application for nylon.

Acrylics are exceptionally soft to the touch and have natural warmth and resilience. Their largest uses are as replacements for wool in a variety of household and apparel products such as pile fabrics, carpets, blankets and sweaters. Industrial uses are negligible.

Polypropylene is the major polyolefin fiber in the U.S. It is widely used in synthetic turf, where it competes with nylon. It is also used in bagging materials and carpet backing.

Other synthetic fibers include spandex, used largely in foundation and other garments where stretch is desired; saran, used for upholstery in public conveyances, garden furniture, awnings, etc.; and vinyon, used as a bonding agent for non-woven fabrics and products.

PRODUCTION

Table 5 provides historical information on the non-cellulosic fiber industry including number of employees, value added by manufacture and value of shipments. Overall dollar growth has averaged 9.2 percent per year since 1967. U.S. quantities of production of the major non-cellulosic fibers are shown in Table 4. As can be seen, polyester has grown at a very high rate over the 1968 to 1978 period and surpassed nylon in 1972 as the non-cellulosic fiber with the greatest production by weight.

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[4] Mary K. Meegan, ed., Kline Guide to the Chemical Industry. (3d. ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 198.

TABLE 4

NON-CELLULOSIC ORGANIC FIBERS PRODUCTION
(millions of pounds)

	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Acrylic[a]	726	709	621	525	631	742	626	545	492	533	521
Nylon[b]	2550	2326	2075	1857	2124	2175	1974	1595	1355	1411	1350
Olefins[c]	692	635	577	497	531	492	416	322	262	269	264
Polyester	3800	3642	3340	2995	2926	2888	2328[d]	1142[d]	1022[d]	939[d]	826[d]
Other	16[e]	16[e]	14[e]	12[e]	12[e]	13[e]	11[e]	688[f]	455[f]	376[f]	267[f]
TOTAL	7784	7328	6627	5886	6224	6310	5355	4292	3586	3528	3229

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[a] Includes modacrylic.

[b] Includes aramid.

[c] Includes olefin yarn and monofilaments, and olefin and vinyon staple and tow

[d] Does not include yarn and monofilaments.

[e] Includes only yarn and monofilaments; yarn is chiefly saran and spandex.

[f] Includes only yarn and monofilaments; yarn includes polyester, anidex, saran, spandex, vinyon, and TFE fluorocarbon.

Source: Chemical and Engineering News, June 11, 1979, p. 40.

TABLE 5

NON-CELLULOSIC ORGANIC FIBERS: INDUSTRY STATISTICS

Year	Number of Employees (1,000)	Number of Production Workers (1,000)	Value Added by Manufacture (million dollars)	Value of Shipments (million dollars)
1977	73.0	54.0	2,789.4	6,345.6
1976	69.3	50.2	2,263.7	5,307.3
1975	70.2	51.0	1,983.0	4,933.8
1974	80.9	60.5	2,410.9	4,716.1
1973	81.8	61.5	2,819.0	4,751.2
1972	78.2	58.4	2,039.8	3,638.9
1971	75.2	55.2	1,905.4	3,241.4
1970	75.7	54.6	1,692.6	2,868.8
1969	70.2	50.9	1,703.6	2,713.3
1968	62.1	45.6	1,736.9	2,584.7
1967	57.2	40.7	1,251.8	2,033.2
1966	59.1	40.6	1,301.5	1,991.8
1965	51.5	36.5	1,215.4	1,842.9
1964	44.3	30.7	1,043.1	1,580.6
1963	41.4	28.4	922.0	1,403.2

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

INDUSTRY STRUCTURE

Table 6 lists the numbers of establishments within the non-cellulosic fiber industry. The number of establishments has been relatively small; however, the rate of firms entering the industry in recent years is substantial. DuPont held patents on nylon, polyester, and acrylics throughout most of the 1950's. With the expiration of these patents, however, and the development of polyolefin fibers, many new producers entered the industry.

In spite of the increased number of manufacturers, the industry is still highly concentrated. Table 7 shows the ranking of firms in the man-made fiber industry (including cellulosics) in 1976. DuPont alone accounts for roughly 36 percent of all shipments. The top three firms (DuPont, Celanese, and Monsanto) have a 60 percent share of the market, and the top ten firms have a 91 percent share.

PRICES

Table 8 gives indices of average manufacturers' prices for non-cellulosic fibers from 1966 through 1975. It can be seen that prices had fallen sharply until 1972. In fact, prices fell faster than those of any other product group in the chemical industry for the previous 10 years.[5] Part of the decline was due to a shifting product mix. For example, staple production grew faster than filament yarn, which is less expensive.

Prices of individual products, particularly nylon and polyester, declined significantly during this period. Most of the price decrease was brought about by increased competition. For example, DuPont was the only producer of polyester fiber in 1960, while in 1976, there were eleven relatively large producers.

Beginning in 1973, prices of man-made fibers began to increase because of raw material shortages caused by the oil embargo.

FOREIGN TRADE

Table 9 shows imports, exports and the trade balance in non-cellulosic fibers. The trade balance decreased until 1971 and then made a strong reversal. The turnaround was primarily accomplished by government agreements with Hong Kong, Japan, South Korea, and Taiwan. These countries agreed to

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[5] Meegan, Kline Guide, p. 101.

TABLE 6

NON-CELLULOSIC ORGANIC FIBERS INDUSTRY ESTABLISHMENTS

Year	Total Number of Establishments	Number of Establishments With 20 Employees or More
1977	65	57
1972	40	35
1967	25	24
1963	14	14

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures. (Washington, D.C.: Government Printing Office, 1979).

TABLE 7

MAJOR U.S. PRODUCERS OF MAN-MADE FIBERS: 1976

Rank	Company	Man-Made Fibers Sales (Million $)	Total Chemical Sales (Million $)	Man-Made Fibers % of Total
1	DuPont	2,025	7,300	27.7
2	Celanese	850	1,855	45.8
3	Monsanto	625	3,577	17.5
4	Eastman Kodak	425	1,247	34.1
5	Akzona	300	490	61.2
6	Allied Chemical	300	1.738	17.3
7	Avtex Fibers	300	300	100.0
8	American Hoechst	155	600	25.8
9	Dow Badische	150	300	50.0
10	Hercules	145	1,375	10.5
11	Standard Oil of Indiana	125	1,432[a]	8.7
12	American Cyanamid	95	1,096	8.7
13	Beaunit	85		
14	Courtaulds of North America	80		
15	Standard Oil of California	75	685	10.9
	OTHER	65		
	TOTAL	5,800		

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[a] Includes fabricated plastics.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Company, 1977), pp. 7 and 101.

TABLE 8

INDICES OF AVERAGE MANUFACTURERS'PRICES OF NON-CELLULOSIC FIBERS
1967 = 100

Year	Price
1966	115.4
1967	100.0
1968	92.5
1969	86.2
1970	82.1
1971	78.3
1972	65.6
1973	74.6
1974	74.0
1975	81.9

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 102.

TABLE 9

U.S. FOREIGN TRADE IN MAN-MADE FIBERS: 1967-1976
(millions of dollars)

	Imports[a]	Exports[a]	Trade Balance[a]
1967	81	153	72
1968	137	172	35
1969	109	189	80
1970	221	226	5
1971	363	231	-132
1972	319	234	- 85
1973	280	419	139
1974	242	629	387
1975	138	432	294
1976	189	492	303

[a] Includes data from glass fibers.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 102.

limit the annual increase of their exports to the U.S. to only five to seven percent. Their average annual rates of growth had been 33 percent between 1963 and 1971.[6]

INNOVATION

During the first generation of non-cellulosic organic fibers, chemists developed basic fiber technology. At that time, each of the fibers was made in one form. During the next phase of development each of the generic fibers underwent modification to improve both performance and aesthetics. This was a time of problem-solving and the exploration of designs for end use. Now most generic fibers are made in many different versions, each engineered to suit a particular product.

Every man-made fiber has both positive and negative characteristics for particular uses. At one time nylon was considered the universal fiber, the best for all applications. But experience proved that nylon has limitations, such as relatively poor recovery from deformation. Hence, it is prone to wrinkling in wear and is not well adapted to many outerwear applications. Nylon has also had the problem of static build-up, which triggers shocks to people walking on nylon carpeting.

This static problem was addressed successfully by both Monsanto and DuPont. In 1969, Monsanto introduced the first permanently altered antistatic nylon fiber, 22N. Later in the year, DuPont introduced its textile fiber, Antron. Production of 22N involves dispensing an ethoxylated hydrocarbon as a second phase in the polymer matrix before the fiber is formed. In the finished yarn, this dispersed phase reduces the fiber's electrical resistivity, which allows static charges to dissipate rapidly. This virtually eliminates shocks normally experienced after walking on nylon carpets.

There are a great many such stories within the non-cellulosic organic fibers industry. There are literally hundreds of variants for each non-cellulosic organic fiber. Each variant has somewhat different characteristics. A number of new products have been introduced over the years--some involving changes to the chemistry and some involving physical changes to the fibers. The development of bi-component fibers is an example of a physical change. Bi-component fibers are composed of two generically similar but chemically or physically different polymers, physically joined in a single filament. In processing, or in later fabric finishing, one component shrinks more than the other thus pulling the whole yarn into a crimped conformation, a desirable aesthetic quality.

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[6] Ibid.

It appears that non-cellulosic organic fiber manufacturers are now accelerating the trend toward engineering fibers to specific, narrow end uses. They are also still concentrating on producing products that look and feel like cotton, wool, silk, or linen.

The chances do not seem to be too high of developing and producing a new generic fiber that differs radically from those now made and that would compete successfully with today's major fibers.[7] Not only would finding such a fiber be difficult in this well-researched field. but the cost of building a plant with a large capacity and then establishing that new fiber in the man-made fiber market would seem to require a large amount of resources.

The last generic fiber introduced was anidex in 1969. Rohm & Haas reputedly spent $20 million and 10 years of research to develop it [8] A 1977 estimate by an industry executive was that a minimum of $50 million and 5 to 10 years of development would be required to commercialize a new generic product for broad-based market application.[9]

We belive that, for the forseeable future, new product development in the non-cellulosic fiber industry will continue at a rapid rate, but will involve modifications of existing products for enhanced performance and aesthetic characteristics.

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[7] American Chemical Society, Chemistry in the Economy, p. 112; Robert L. Stultz, Jr., and "Fibers through the Crystal Ball: No New Generics, Just Variants," Textile World. December 1977, pp. 73-74.

[8] American Fabric Magazine, Encyclopedia of Textiles, p. 47.

[9] Stultz, "Fibers Through the Crystal Ball," p. 74.

E-115

Synthetic Rubber

SYNTHETIC RUBBER

DESCRIPTION

Synthetic rubbers (also known as synthetic elastomers) are part of a group of materials called polymers which also include plastics and organic fibers. An elastomer is any polymeric material capable of recovering quickly and forcibly from large deformations such as stretching, bending, or twisting. Generally, a cured elastomer (1) can be stretched to at least three times its original length at room temperature and (2) after being held at twice its original length for one minute, will return to no more than 1.5 times its original length within five minutes.

The basic chemical elements of synthetic elastomers are carbon, hydrogen, nitrogen, and oxygen. These elements are combined in specific ways to build long chains of molecules with carbon "backbones". Synthetic elastomers can be divided into three categories: (1) the general-purpose type, which includes butyl, ethylene-propylene, polybutadiene, polyisoprene, and styrene-butadiene; (2) the specialty, solvent-resistant type, which includes epichlorohydrin, epichlorohydrin-ethylene oxide. nitrile, polychloroprene (neoprene), polysulfides (Thiokol), and the polyurethanes (polyester and polyether); and (3) the specialty, heat-resistant type, which includes chlorosulfonated polyethylene (Hypalon), fluoroelastomers, polyacrylates, and silicone. For each of these types there are a number of variants.

HISTORY

Synthetic rubber was first produced commercially in Germany during World War I. In 1931, DuPont introduced the first synthetic rubber of great importance, polychloroprene (neoprene), and Thiokol Corporation at about the same time announced a polysulfide rubber it called Thiokol. Despite all their good properties, neither Thiokol nor neoprene proved to be a truly general-purpose synthetic rubber that could compete with natural rubber in its many uses.

Standard Oil Company (New Jersey). interested in coal liquefaction because of rising demand for gasoline. signed an agreement in 1927 with I.G. Farbenindustrie of Germany to exchange information on making oil from coal. The next year, the East Texas oil field was discovered and the U.S. oil industry shifted from scarcity to surplus. The coal liquefaction work was suspended, but the agreement with I.G. Farbenindustrie was extended to include making chemical raw materials (including synthetic rubber) from oil. The Germans developed two synthetic rubbers and shared information with Standard Oil under terms of the agreement. One was called Buna S, a butadiene-styrene elastomer that was viewed as a general-purpose rubber. The other was called Buna N, a butadiene-acrylonitrile elastomer that was viewed as an oil-resistant rubber.

Although the original Buna S and Buna N rubber products were of poor quality, they formed the technological basis for synthetic rubber production in the United States. The U.S. Government, the four major rubber companies, and Standard Oil Company (New Jersey) agreed in December 1941 to pool their information on styrene-butadiene rubbers. Other companies later joined the agreement. Within a short time, chemists developed a new all-purpose rubber that could be processed on conventional equipment, and could improve the quality of tires.

The U.S. synthetic rubber industry was established on a high-volume basis during World War II when the government, anticipating the loss of natural rubber sources, built enough synthetic rubber production capacity to meet wartime requirements. Styrene-butadiene rubber (SBR) was selected as the synthetic to substitute for natural rubber. In addition, plants for such specialty synthetics as butyl. nitrite, and neoprene were also built. Production of all types of synthetic rubber rose from 2.940 long tons in 1940 to 820,373 in 1945, when synthetic rubber constituted 86.9 percent of all consumed rubber products.1/

Under the Rubber Producing Facilities Disposal Act of 1953 the government sold its plants to private industry in 1955. The oil, chemical, and rubber companies that had managed the properties for the government were the successful bidders.

ENGINEERING PROCESS

There are four basic steps in processing synthetic elastomers. First, the polymer is prepared from the monomer or monomers; this process is called olymerization. If only one type of monomer is being polymerized, it is called homopolymerization. If more than one type of monomer is involved, it is called copolymerization. The polymerization step includes the receipt, storage, and mixing of additives. solvents or suspending media, and monomers.

Second, the material is compounded or mixed and blended with other polymers. vulcanizing agents, and other rubber-processing chemicals to obtain the required properties.

The third step involves shaping or forming the compound either by extrusion, calendering or molding. Considerable quantities of elastomers are also applied in the form of water dispersions, called latexes. Most latex is made into foam rubber, but there are other important applications in paints, paper coatings, textile coatings and backings, and such dipped rubber goods as gloves and drug sundries.

1/Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Company, 1977), p. 103.

In the fourth step of processing synthetic elastomers, the elastomer is vulcanized to obtain the characteristic elastic or rubbery qualities. Vulcanization also improves strength. hardness and other physical properties. Sulfur is the most common vulcanizing agent, but many specialty rubbers use peroxides, resins. and other chemicals. Even when vulcanized, some rubbers are weak, particularly at higher temperatures, and they need reinforcing for strength. Fine colloidal fillers, particularly carbon blacks and silicas, are used. Sometimes softeners and plasticizers are added to make rubber easier to process or to make it more flexible at low temperature.

RAW MATERIALS

The synthetic rubber industry draws almost entirely on chemicals derived from petroleum and natural gas. The industry is the major consumer of butadiene[2] which is produced from butane, a byproduct of petroleum refining or natural gas manufacture. Other important petroleum derivatives include benezene (for producing styrene); isobutylene and isoprene (for producing butyl); propylene (for producing acrylonitrile and nitrile); and chloroprene (for producing polychloroprene). The synthetic rubber industry is quite sensitive to petroleum refining development.

The synthetic rubber industry consumes a large amount of carbon black. In 1977 this consumption amounted to about 12 percent of the total carbon black shipped in that year.[3] Soaps and detergents, plasticizers, and rubber processing chemicals are also used in significant amounts.

USES

The predominant use of synthetic as well as natural rubber is in the automotive industry with tires, tubes. and related tire products, accounting for 57.7 percent of all synthetic rubber consumed in 1976.[4] Other major uses are shown in Table 1.

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[2] U.S. Department of Commerce, 1978 U.S. Industrial Outlook, Washington, D.C.: Government Printing Office, 1978) p. 145.

[3] Calculated from data in U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures, (Washington, D.C.: Government Printing Office, 1979).

[4] Meegan, Kline Guide, p. 106.

TABLE 1

U.S. CONSUMPTION OF SYNTHETIC RUBBER BY MAJOR END USE: 1976

	Percentage of Tonnage
Tires, tubes and tire products	57.7
Molded goods	
Industrial rubber	11.0
Automotive	4.7
Footwear	3.0
Plastic impact modifiers	1.8
Belting, hoses and gaskets, etc.	1.8
Wire and cable	1.4
Adhesives	1.2
Coatings	1.1
Other	16.3
Total	100.0

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Charles Kline & Co., 1977), p. 106.

In 1940, natural rubber (new or reclaimed) held 99.6 percent of the U.S. market.[5] By 1951 synthetic rubber had a 53 percent market share and a 69 percent share by 1960.[6] By 1976, this share had risen to about 75 percent.[7] This success was achieved despite the fact that until the development of the "stereo rubbers" (polybutadiene, polyisoprene, etc.) in the 1960s there were no synthetic rubbers that duplicated the excellent elastomeric properties of natural rubber. The success of synthetic rubber may be explained in part by the fact that world production of natural rubber is inadequate for world demand. Also, styrene-butadiene rubber the largest volume synthetic, is less expensive than natural rubber.[8]

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[5] American Chemical Society, Chemistry in the Economy, a study supported in part by the National Science Foundation, 1973, p. 116.

[6] *Ibid.*.

[7] Meegan, Kline Guide. p. 103.

[8] *Ibid.*, p. 104.

Table 2 lists the primary uses and important characteristics of the major types of synthetic rubber. In addition to the types of synthetic rubber listed in the table are such specialty elastomers as chlorosulfonated polyethylenes, polysulfides, fluorocarbons, polyacrylates, polyurethanes, and silicones. Synthetic rubbers can be seen to compete with each other in addition to competition with natural rubber.

Synthetic rubber has probably nearly reached the saturation point regarding further penetration into the markets for natural rubber.[9] The increasing wearlife of tires, and the consequent reduction in consumption of replacement tires. is another factor which has contributed to slow growth within the synthetic rubber industry. One other factor was the 1976 strike in the industry and the resultant increases in market share achieved by foreign competitors.

The automotive market will likely continue to dominate rubber usage. Growth in auto production is not expected to be strong over the next few years.[10] This is a negative factor in the synthetic rubber industry's growth projections. However the trend in the future will probably continue to be toward more fuel efficient, lighter cars. Rubber products can play a part in this trend by replacing some heavier metal automobile parts.

PRODUCTION

Table 3 provides historical information on the synthetic rubber industry including number of employees, value added by manufacture and value of shipments. The annual dollar growth in shipments averaged 7.5 percent between 1967 and 1977. U.S. production volumes of synthetic rubber are shown in Table 4. The growth rate during the 1966 to 1976 period in production volumes averaged 3.4 percent. The difference between the two growth rates can be attributed to the fact that average prices have increased.

The most rapidly growing segment of the synthetic rubber industry has been projected to be the specialty elastomers, usually of much higher value than general purpose materials.[11] This will cause the value of shipments to increase more rapidly than the quantity of shipments.

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[9] Ibid..

[10] U.S. Department of Commerce, 1978 U.S. Industrial Outlook. p. 145.

[11] Ibid., p. 146.

TABLE 2

MAJOR USES AND CHARACTERISTICS OF IMPORTANT SYNTHETIC RUBBERS

Synthetic-Rubber	Major Uses	Characteristics
Styrene-butadiene	Passenger car tire treads, tire carcasses, mechanical goods, and carpet backing.	Good wear characteristics due to high resistance to abrasion, heat, and tread cracking.
Polybutadiene	Tire treads.	Excellent abrasion resistance, high resiliency, and excellent high- and low-temperature properties. Contributes to better resistance to groove cracking. Limitations include poor wet-skid resistance and cutting and chipping in heavy-duty truck tire treads.
Polyisoprene	Passenger and truck tire carcasses, and truck treads, mechanical goods, rubber footwear, and latexes.	Chemically identical with natural rubber. More expensive than natural rubber, but cleaner, lighter in color, and more uniform from batch to batch and therefore cheaper to process.
Ethylene-propylene	Bicycle tires, white walls, other side-walls, molded automotive parts and other mechanical goods.	Poor adhesion and slow cures which make them difficult to blend with other rubbers. Potentially low cost, outstanding resistance to oxidation and cracking, and low-temperature flexibility.
Neoprene (polychloroprene)	Belts, hoses, molded products, general industrial and mechanical goods, wire and cable jackets, construction, adhesives, sealants, and coatings.	One of most versatile elastomers with high resistance to oils and solvents, superior tensile strength and resistance, and high resistance to abrasion and oxidation.
Butyl	Inner tubes, inner liners, inflatable sporting goods, liners for reservoirs and grain silos, automotive and mechanical goods, architectural and industrial sealants, wire and cable.	Low permeability to gases and excellent tear and aging resistance.
Nitrile	Self-sealing fuel tanks, gasoline hose, gaskets, printing rolls, seals, adhesive and footwear.	Good oil resistance.

Sources: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), pp. 103-108; and American Chemical Society, Chemistry in the Economy, a study supported in part by the National Science Foundation (1973), pp. 116.

TABLE 3

SYNTHETIC RUBBER INDUSTRY STATISTICS

Year	Number of Employees (1,000)	Number of Production Workers (1,000)	Value Added by Manufacture (million dollars)	Value of Shipment (million dollars)
1977	10.1	7.2	570.1	1,866.8
1976	10.6	7.6	510.7	1,702.3
1975	9.9	7.0	468.8	1,455.7
1974	10.7	7.5	531.5	1,481.1
1973	11.2	7.8	475.2	1,167.6
1972	11.8	8.2	491.7	1,089.4
1971	12.2	8.2	476.7	1,042.6
1970	12.8	8.7	460.9	1,006.6
1969	12.5	8.5	500.7	1,046.2
1968	12.2	8.3	453.0	974.2
1967	12.6	8.5	404.9	926.9

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

TABLE 4

U.S. PRODUCTION OF SYNTHETIC RUBBER
(millions of pounds)

	1966	1974	1975	1976
SBR	2,448	3,135	2.608	2,980
Stereo-specific Polybutadiene	417	793	656	752
EPDM	196	279	187	303
Polyisoprene	[a]	188	135	[a]
Stereo-specific Subtotal	613+	1,260	978	1,055[a]
Butyl	231	354	182	277
Nitrile	157	206	119	166
Urethane	12	88	51	81
Silicone	13	44	31	39
Other[b]	455	655	610	869
	3,929	5,742	4,579	5,467

[a] Additional amounts included in "other" elastomers.

[b] Includes polychloroprene, chlorosulfonated polyethylene, polysulfide, silicone, fluorocarbon, thermoplastic rubber and miscellaneous elastomers.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 105.

INDUSTRY STRUCTURE

Table 5 lists the number of establishments within the synthetic rubber industry. In 1976, there were 39 companies producing synthetic rubber through 60 establishments.[12] Fourteen of these companies accounted for almost 90 percent of the dollar shipments in 1976. Table 6 lists the major firms in the industry with their estimated sales of synthetic rubber and total chemical sales in 1976. The estimates include the value of production consumed within the firm.

It can be seen that the industry is dominated by tire and oil companies. DuPont, Copolymer Rubber and Chemical. Ashland, and Petro-Tex are the only major producers that are primarily chemical companies. This tire and oil company dominance can be traced to the origins of the industry as described earlier. Styrene-butadiene and the "stereo rubbers" (polybutadiene, and polyisoprene, etc.) are produced by many of the firms in Table 6 while at the other end of the spectrum, butyl and neoprene are produced by few firms.[13]

TABLE 5

SYNTHETIC RUBBER INDUSTRY ESTABLISHMENTS

Year	Total Number of Establishments	Number of Establishments with 20 Employees or more
1977	62	31
1972	59	34
1967	48	28
1963	24	24

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

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[12] Meegan, Kline Guide. p. 106.

[13] Ibid.

TABLE 6

MAJOR U.S. PRODUCERS OF SYNTHETIC RUBBER: 1976

Rank	Company	Synthetic Rubber Sales[a] ($ million)	Capacity
1	Goodyear Tire & Rubber	320	610
2	Firestone	250	495
3	DuPont	230	240
4	B.F. Goodrich	150	275
5	Exxon Chemical	140	190
6	Copolymer Rubber & Chemical	95	160
6	General Tire & Rubber	95	190
8	Texas--U.S. Chemicals	90	180
9	American Synthetic Rubber	75	160
10	Phillips Petroleum	65	125
10	Uniroyal	65	75
12	Ashland Chemical	30	55
13	Cities Service	25	37
13	Petro-Tex Chemical	25	30
--	Other	245	NA
	Total	1,900	--

[a] Includes captive consumption as well as merchant sales.

NA: Not available.

Source: Mary K. Meegan. ed., Kline Guide to the Chemical Industry. (3rd ed.. Fairfield. NJ: Charles Kline & Co., 1977), p. 107.

Many domestic rubber plants in use were constructed during World War II. Improvements in design and processing at new plants make many of these old plants comparatively inefficient. In recent years there has been relatively little new capital investment in the industry because of ample capacity.

PRICES

Table 7 gives indices of average manufacturers' prices for selected synthetic rubber. Until 1970, prices were fairly stable. In 1971 prices fell 4.8 percent from the 1970 average. Between 1971 and 1976 average prices increased 60.4 percent.

TABLE 7

INDICES OF AVERAGE MANUFACTURERS' PRICES
OF SELECTED SYNTHETIC RUBBERS: 1967-1976
1967=100

Year	Styrene-butadiene	Nitrile	Stereo-specifics	Urethanes	Silicones	Total
1967	100.0	100.0	100.0	100.0	100.0	100.0
1968	104.1	99.7	97.6	99.4	92.4	101.9
1969	103.2	101.5	96.6	106.3	95.0	100.7
1970	104.5	101.5	95.1	98.3	94.3	100.7
1971	90.9	98.7	91.2	106.6	81.1	95.9
1972	90.9	95.3	97.1	116.4	71.0	98.9
1973	72.7	95.7	104.8	109.0	66.1	92.6
1974	109.1	108.7	142.9	119.0	73.8	122.2
1975	122.7	123.9	142.9	130.0	93.5	137.0
1976	121.3	132.5	172.2	128.9	89.0	153.8

Source: Mary K. Meegan, ed.. Kline Guide to the Chemical Industry, (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977). p. 108.

FOREIGN TRADE

Table 8 shows imports, exports, and the trade balance in synthetic rubber. As can be seen, exports have fluctuated over the period. Overseas synthetic rubber production capacity has grown significantly over the last several decades. The U.S. currently has less than half the world's synthetic rubber capacity.[14] In 1957 the U.S. accounted for 88 percent of the non-Communist world's production of synthetic rubber.[15] In that year, U.S. exports were 18 percent of total U.S. production. In 1976, exports accounted for only 11.8 percent of this production.[16] Exports are expected to continue to fall as additional foreign production capacity is added.

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[14] Ibid.

[15] Ibid.

[16] Ibid.

TABLE 8

SYNTHETIC RUBBER FOREIGN TRADE

(million of pounds)

Year	Imports	Exports	Trade Balance
1972	249.8	602.8	353.0
1973	304.0	657.2	353.2
1974	249.5	631.2	381.7
1975	203.9	510.2	306.3
1976	273.5	623.3	349.8
1977	367.0	559.1	192.1

Source: David B. Beck, "Synthetic Elastomers: Role of U.S. Imports," Synthetic Organic Chemicals, U.S. International Trade Commission 1977, p. 243.

Exports of styrene-butadiene rubber have been particularly affected as much of the foreign production capacity is for this type of rubber.17/ In 1963 exports of styrene-butadiene rubber accounted for 15.2 percent of U.S. production, while in 1976 exports only accounted for 6.0 percent.18/

Imports of synthetic rubber also fluctuated over the 1972 to 1977 period. On the average 5.4 percent of total U.S. consumption was supplied by imports.19/ In 1977 Canada and Japan supplied most of these imports, 52 and 23 percent respectively, with the remainder coming from Western European countries.20/

17/*Ibid*., p. 107.

18/*Ibid*., p. 104.

19/David B. Beck, "Synthetic Elastomers: Role of U.S. Imports," Synthetic Organic Chemicals, U.S. International Trade Commission, 1977, p. 245.

20/*Ibid*.

For the 1972 to 1977 period, styrene-butadiene rubber accounted for about one-third of total imports; polybutadiene, about one-fourth; and butyl rubber, about 15 percent. In 1977 for the first time, polybutadiene (34 percent of total imports) surpassed styrene-butadiene (24 percent) as the leading import.[21]

In 1977 imports rose to a record level of 6.4 percent of U.S. consumption,[22] mostly due to an increase in polybutadiene imports. U.S. production capacity was insufficient to meet the increased demand for polybutadiene because of increased truck and bus tire production. This capacity situation was seen as temporary because U.S. tiremakers were replenishing the inventories that had been depleted as a result of the 1976 strike.

Imported synthetic rubber is generally comparable in quality to U.S. products. The average unit value of imports (including insurance and shipping costs) was one to four cents lower than the average value of U.S. sales during 1972 to 1977.[23] U.S. producers are able to compete for two reasons: (1) the overall U.S. product mix is different from the imports, and (2) the roximity of U.S. producers to their customers provides more rapid response to customer needs and a steady availability of supply. Also, many imports from Western Europe and elsewhere are intracompany transfers, some of which are valued below the domestic market price.

INNOVATION

The history of the synthetic rubber industry has been characterized by the development of new types of synthetic rubber and improved versions of existing types. An example of the latter is styrene-butadiene which, over the years. has become a vastly different and improved product due to better polymerization techniques, new types of modifiers, and improved compounding materials.

It appears that a novel synthetic rubber that would challenge the established ones in more than small specialty markets would face stiff competition. Increment improvements will, however, continue to be made in existing synthetic rubbers. These improvements will largely be the result of process innovations and the development of new additives. The latter are discussed in the section on rubber processing chemicals.

ICF believes that specialty elastomers production will to grow faster than any other synthetic rubber. This part of the industry is characterized by significant innovation since products are engineered to specific uses.

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[21] *Ibid*., p. 245.

[22] *Ibid*., p. 245.

[23] *Ibid*., p. 247.

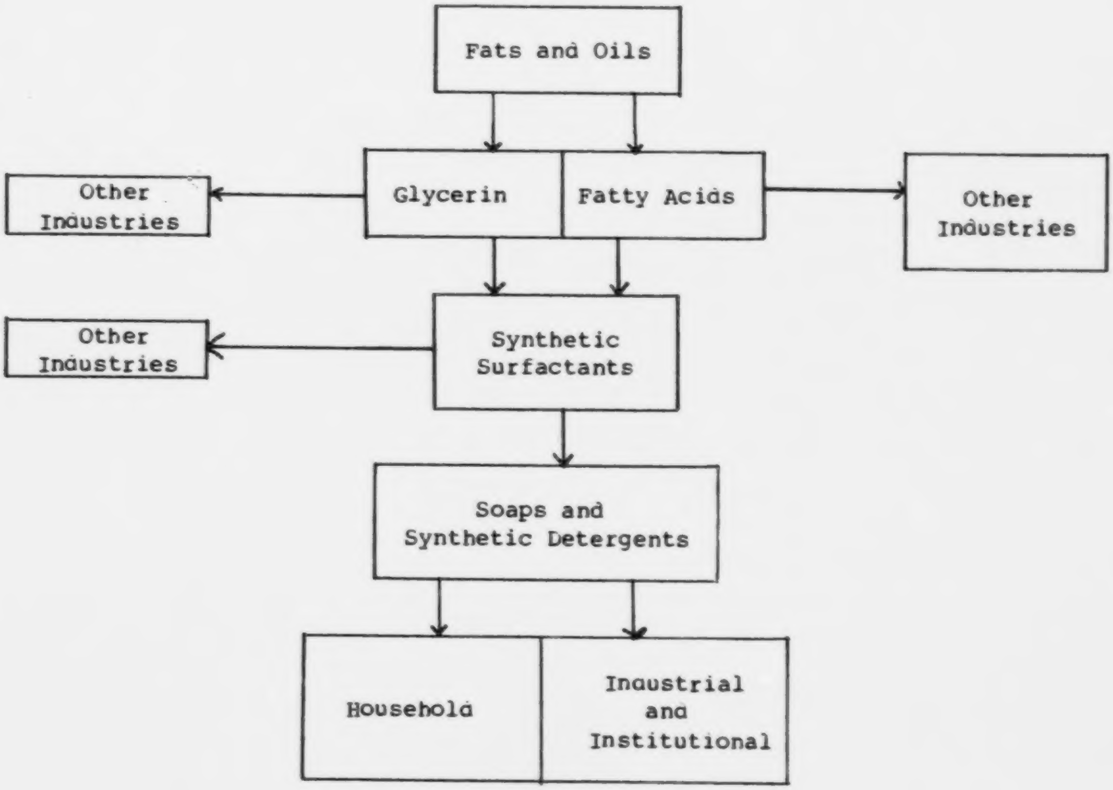
AMPHIPATHIC COMPOUNDS

AMPHIPATHIC COMPOUNDS

All amphipathic compounds have two parts to them. The hydrophilic part, or hydrophile, is soluble in water. The hydrophobic (lipophilic) part is soluble in oil. Usually these molecules are large enough for each part to display its own solubility behavior. The parts that are not soluble in the particular chemical environment surrounding them are chemically attracted to each other. As a result, the molecules huddle together with the insoluble parts forming their own environment inside the huddle. These huddles, called micelles, are of microscopic size and are spherically shaped. Particles not soluble in the solution may be dissolved in these micelles. This is what accounts for the relatively high dissolving capabilities of many amphipathic compounds such as detergents.[1]

FIGURE 1

FLOW CHART OF THE INDUSTRIES



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[1] Robert T. Morrison and Robert N. Boyd, Organic Chemistry (3rd ed., Boston: Allyn and Bacon, Inc., 1973), p. 1060.

This section discusses the chemicals and industries in SIC 2841, SIC 2843, and SIC 28992. These industries have many connections and common characteristics, but also differ in many ways. The profile will be divided into three major sections:

1) Surfactants;

2) Fatty Acids and Glycerin; and

3) Soaps and Synthetic Detergents.

Both the fatty acid and the synthetic surfactant industries are major suppliers of the soap and synthetic detergent industry. The fatty acid industry also supplies the synthetic surfactant industry and glycerin is a byproduct of fatty acid production.

Finishing agents and assistants, which form a segment of SIC 2843, are not covered in this report because:

(1) they are not connected chemically to the rest of the industry, and

(2) they are not a significant industry with regard to sales ($172 million in 1977) or innovation.

Because natural glycerin is a byproduct of fatty acid production and has no chemical relation to soaps or synthetic detergents, it is discussed with fatty acids although it is part of SIC 2841 (Soaps and Detergents). The synthetic glycerin market (SIC 2869) is included here, because it is difficult to discuss the natural glycerin market alone.

Products that fall under SIC 2842 (Polishes and Sanitary Goods) and SIC 2844 (Toilet Preparations, Perfumes) are mentioned in Soap and Synthetic Detergents because they share common chemical characteristics and are produced by the same companies.

Within the report, several terms are used whose definitions should be clear at the outset.

(1) Synthetic detergent: a product synthetically manufactured, usually including a surfactant, builders, and other components. Synthetic detergents are used for textile cleaning, dishwashing, hard surface cleaning, etc.

(2) Detergent: a compound that reduces surface tension; specifically, a surface-active agent which concentrates at oil-water interfaces, exerts emulsifying action, and thus aids in cleaning surfaces.

(3) Detergent industry: the industry producing synthetic detergents.

(4) Surfactant: a detergent. Surfactant is a commonly used term, short for surface active agent. In this report, "surfactant" and "synthetic surfactant" are synonmous.

(5) Soap: a detergent derived directly from natural fatty acids.

(6) Cleansing bar: a bar of soap used for personal hygiene.

Surfactants

SURFACTANTS

DESCRIPTION

Surface active agents (surfactants) are organic compounds that reduce surface tension. They wet surfaces easily, remove and suspend dirt, disperse particles, emulsify oil and grease, and produce foam. They are sometimes called wetting agents, detergents, penetrants, dispersants, emulsifiers, or foaming and frothing agents.

Different surfactants have different optimal concentrations called micelle concentrations. These concentrations vary with temperature, the presence of inorganic salts, and the pH level.

SHIPMENTS AND GROWTH

In 1977 total production of surfactants was 4,718 billion pounds, a 3.0 percent increase over 1976.2/ Sales increased 6.6% to $875 million. The average unit value was $35 per pound.3/ The industry is expected to grow at two percent or three percent annually4/ because the major use of surfactants--detergents--is also growing at that pace. (See Table 1: Economic Indicators for Surfactants.) Some industrial applications are expected to grow faster, but most analysts believe the slow growth rate of household detergents will limit surfactant growth. Present capacity should be sufficient through most of the 1980s.

PRODUCTS AND USES

The four types of surfactants are differentiated by their electrolytic behavior. Anionics, the major group. have a hydrophile with a negative charge, cationics have a hydrophile with a positive charge, nonionics have a hydrophile with no charge, and amphoterics exhibit anionic and cationic behavior depending on the pH of the solution they are in.

2/U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

3/Ibid.

4/Ibid.; and Chemical and Engineering News. May 22, 1979.

TABLE 1

ECONOMIC INDICATORS FOR SURFACTANTS

XXX	1975	1974	1973	1972	1971	1970	1969	1968
Employees (thousands)	6.7	7.8	6.3	6.9	6.6	6.4	5.8	5.9
Payroll (millions)	91.4	95.2	73.2	71.5	68.5	60.4	57.7	54.9
Production workers (thousands)	3.7	4.4	3.4	3.8	3.5	3.4	3.0	3.2
Manhours (millions)	7.8	9.2	6.8	7.7	7.3	7.0	6.2	6.5
Wages (millions of dollars)	42.4	46.6	32.5	32.3	30.0	26.6	22.7	22.7
Value added (millions of dollars)	269.7	334.3	211.3	209.5	173.3	163.3	151.4	141.5
Cost of materials (millions of dollars)	431.0	483.0	277.7	257.0	215.6	212.3	174.6	187.6
Value, industry shipments (millions of dollars)	705.6	797.5	488.5	462.6	388.3	375.1	324.0	328.9
New investments (millions of dollars)	34.7	31.6	25.1	19.7	19.8	21.9	8.3	9.1
End of year inventory (millions of dollars)	100.6	117.4	66.6	61.4	52.3	48.9	42.5	40.7

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

The anionics, which include natural soaps, accounted for 79 percent of total surfactant production in 1977. Lignosulfonates[5] (also called lignin sulfonates), the major anionic group, accounted for 24 percent with 1.160 billion pounds. They are obtained as byproducts of sulfite pulping, and are one of the least expensive surfactants. They are used in drilling muds for oil wells, dye dispersants, ceramic binders, concrete admixtures, gypsum board, animal feeds, carbon black, and industrial cleaners.

Alkylbenzene sulfonates, the largest group of lignosulfonates, accounted for 13 percent (632 million pounds) of total surfactant production in 1977. They have good detergent and "sudsing powers" and are used in most heavy-duty laundry powders. In the past they were inexpensive because they were made from cheap, abundant, petrochemical starting materials and were produced on a low margin. Because of rising oil prices, they are losing some of their market to non-petroleum derived surfactants.

Until 1963 alkylbenzene sulfonates (ABS) were derived from tetrapropylene benzene and contained a branched benzene ring. This made them non-biodegradable and led to environmental problems (see History). Linear alkylbenzene sulfonate (LAS) replaced them but is still not totally acceptable. It breaks down slowly and incompletely, and has been banned in many areas. The use of fat-based detergents, the most important of which are the linear alkyl alcohols. has been growing because of their complete biodegradability.

The move toward lower phosphate levels has hurt the market for LAS (see History). Lower phosphate levels require higher concentrations of surfactant. but they are anionics, which foam too much in high concentrations. Because they also are not as effective as nonionics and cationics in hard water, they have been replaced by nonionics. In the nonphosphate detergents, nonionics account for 70 percent of the surfactants used and anionics account for the rest. Other less important anionic sulfonates include the benzene, cumene, toluene, xylene, and naphthalene sulfonates; the sulfosuccinamates; the sulfonsuccinates; and the taurates.

Another group of anionics, sulfates,[6] accounted for 11.3 percent (524 million pounds) of total surfactant production. Ether sulfates are primarily used as auxiliary surfactants with LAS in light-duty dishwashing liquids and delicate fabric detergents. They are also used in shampoos and bubble baths. Alcohol sulfates are primarily used in cosmetics and toiletry products, and remaining sulfates are used in the plastics industry.

The other major anionic group is phosphate and polyphosphate surfactants, which had a production of 38 million pounds. These have excellent wetting, emulsifying, detergent, and anticorrosive characteristics, but are very expensive. They are used mostly for emulsion polymerization, latex stabilization, antistatic effects, dispersants, textile scouring, and general purpose cleaners. Other anionics include sarcosinates, polypeptides, xanthates, and sulfonates. Natural soap is also anionic, but is not covered in this section.

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[5] Sulfonation is the formation of a sulfuric acid, i.e., a compound containing the SO_2OH group. A common sulfonating agent is concentrated sulfuric acid.

[6] Sulfates contain H_2SO_4 esters. They are not as stable as, and are more hydrophilic than, sulfonates.

Nonionics accounted for 25 percent of the total production of surfactants in 1977 (1.2 billion pounds). Nonionics are compatible with anionic surfactants, cationic surfactants, and most builders because they do not ionize.

The most important group of nonionics is the ethylene oxide condensates. Alcohol ethoxylates[7] are primarily used as auxiliary surfactants in heavy-duty laundry detergents. Some are also used as intermediates for anionic ether sulfates. Alkylphenol ethoxylates are used in textile processing, petroleum oils, pesticides, paper manufacture, emulsion polymerization, and as intermediates for sulfate surfactants.

Anhydrosorbitol esters and ethoxylated anhydrosorbitol esters[8] are used in foods, cosmetics, and toiletries. Glycerol esters are used in foods, and polyethylene glycol is used in foods and textiles. Fatty acid alkanolamides are used as dispersants and foaming agents.

Cationics accounted for 6.3 percent of the total production of surfactants (297 million pounds) in 1977. The most important group, the salts of higher alkyl amines, are used as ore flotation agents, corrosion inhibitors, dispersants, foam builders, softeners, and petroleum demulsifiers. The quaternary ammonium salts have good wetting and germicidal properties and are used in fabric softeners, germicides, and dye stuff fixatives. Cationics in general are expensive and cannot be used with anionics; this severely limits their use.

Amphoterics accounted for .3 percent (18,000 pounds) of total surfactant production in 1977. They are used in cleansing bars and shampoos and are unique in their ability to control detergency. However, they are very expensive.

About one half the total surfactant production is used in household detergents. Other major markets are industrial cleaning products, oil well drilling, breaking of crude oil emulsions, secondary oil recovery, pesticides, textile processing, metal processing, foods, ore flotation, paints, metal cleaning, elastomer and polymer production, and lubricants.

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[7] Ethoxylates are chemicals containing ethylene oxide, which provides solubility in water.

[8] Esters are organic compounds that correspond in structure to salts in inorganic chemistry.

HISTORY

The first synthetic surfactants were developed in Germany during World War I because of a shortage of natural fats.[9] They included sulfated fatty alcohols, fatty aryl taurides, and isethiomates. and were used in textile manufacturing. In the 1920s, the first commercially feasible sulfonated surfactants were developed by the chemical and dye manufacturers who supplied the textile industry. Although Germany continued to be the leader in this field, the United States, Great Britain, France. and Switzerland quickly caught up.

Alcohols were first ethoxylated in 1929 by I.G. Farben (Germany), and Union Carbide and Rohm Haas were responsible for developing nonionic surfactants in the United States.

In the middle 1930s the first light-duty surfactants were introduced. At the end of World War II their performance was greatly improved from the addition of builders that soften water.

Alkylbenzene sulfonate (ABS) was introduced in the early 1950s, and with it came the explosive growth of the synthetic detergent industry. Over the next two decades production increased 20 times its original amount and in the middle 1960s the nonbiodegradability of ABS, due to its branched nature, was discovered. The industry spent several hundred million dollars to develop linear alkylbenzene sulfonates (LAS).[10]

INDUSTRY STRUCTURE

There are three parts to the surfactant industry: raw material suppliers, producers that sell surfactants, and producers that use most of their productive capacity.[11]

Major suppliers of linear alkylbenzene (LAB). the intermediate used to produce LAS, are Conoco, Monsanto, and Union Carbide (see Table 5). Conoco, Ethyl, and Shell Chemical produce synthetic fatty alcohols[12], and Proctor and Gamble is the only producer of natural fatty alcohols. Nonylphenol, the major alkylphenol,[13] is produced by Borg-Warner, GAF Corporation, Jefferson Chemical, Monsanto, Rohm Haas, and Schenectady Chemicals. Ethylene oxide is produced by BASF Wyandotte, Jefferson Chemical and Union Carbide. Major synthetic surfactant producers are: BASF Wyandotte, Conoco, GAF Corporation, Jefferson Chemical, Monsanto, Rohm Haas, Shell Chemical, and Union Carbide.

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[9] Natural fats are used to make soap.

[10] American Chemical Society, Chemistry in the Economy, a study supported in part by the National Science Foundation, 1973, p. 200.

[11] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 166.

[12] Fatty alcohols are used in anionic surfactants.

[13] Alkylphenol is used in nonionic surfactants.

TABLE 2

U.S PRODUCTION OF SURFACTANTS

(million pounds)

	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Anionics																				
Sulfonates	1961	1942	1780	1832	1524	1335	1278	1331	1305	1271	N/A	N/A								
Carboxylic acids	638	821	735	839	939	907	872	938	959	1044	1044	962								
Sulfates	524	391	374	341	311	330	281	297	338	249	N/A	N/A	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Phosphates & poly-phasphates	39	32	21	31	28	26	27	27	25	22	15	13								
Other	45	170	153	133	165	149	137	135	126	124	135	133								
Total	3207	3356	3062	3176	2967	2747	2595	2728	2753	2710	2614	2469	2358	1434	1369	1361	1238	1074	1068	979
Nonionics																				
Carboxylic acid amides	81	78	82	89	94	88	81	90	83	87	92	93								
Carboxylic acid esters	226	222	222	262	246	224	204	204	179	164	164	146								
Esthers	883	653	742	866	784	737	736	627	706	601	444	444	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Other	6	3	-	-	-	-	-	1	2	2	5	2								
Total	1195	957	1046	1218	1124	1048	1021	922	971	854	704	686	659	581	525	523	446	426	400	342
Cationics	297	252	226	284	260	229	203	228	169	167	154	162	148	98	83	65	37	31	36	32
Amphoterics	18	18	14	19	21	14	10	8	8	8	7	5	5	5	3	65	8	31	36	2
TOTAL	4718	4582	4349	4697	4372	4039	3828	3886	3901	3739	3479	3321	3170	2119	1981	1949	1729	1532	1504	1355

N/A - not available.

(X) There was a change in the classification system that makes disaggregation difficult and inaccurate.

SOURCE: U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

TABLE 3

U.S. SALES OF SURFACTANTS
(millions of dollars)

	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Anionics																				
Sulfonates	164	153	131	132	N/A	78	76	70	78	66	63	60								
Carboxylic acids	51	54	55	66	N/A	17	10	11	11	14	N/A	N/A								
Sulfates	97	91	85	78	58	52	53	43	37	37	N/A	N/A	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Phospphates & poly-phosphates	16	14	12	14	10	10	8	8	9	7	6	5								
Other	9	4	2	-	50	38	40	37	37	42	41	43								
Total	335	316	290	228	195	187	169	172	166	149	141	133	196	187	188	173	169	167	148	
Nonionics																				
Carboxylic acid amides	31	27	29	36	20	18	16	17	15	16	15	19								
Carboxylic acid esters	115	105	95	108	67	57	54	49	45	43	40	40								
Ethers	229	226	185	171	116	100	92	81	74	70	58	60	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Other	5	4	-	-	-	-	-	1	1	2	2	1								
Total	381	362	309	315	202	174	162	148	134	130	116	119	113	108	101	100	93	89	87	71
Cationics	141	123	110	124	89	72	67	64	58	57	48	51	51	43	35	30	21	20	18	15
Amphoterics	19	20	13	17	13	9	7	5	5	5	4	3	3	3	2	30	5	20	18	1
TOTAL	875	821	717	746	532	451	422	387	370	357	317	315	300	350	325	317	292	278	271	235

N/A - not available.

(X) There was a change in the classification system that makes disaggregation difficult and inaccurate.

SOURCE: U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

TABLE 4

U.S. SALES OF SURFACTANTS
(millions of pounds)

	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Anionics																				
Sulfonates	1,038	1,028	897	1039	N/A	774	753	701	683	661	664	671								
Carboxylic acids	134	146	146	177	N/A	48	16	32	31	50	N/A	N/A								
Sulfates	214	234	216	212	223	226	208	189	177	158	N/A	N/A	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Phosphates & poly-phosphates	22	19	16	24	21	21	18	16	18	16	12	9								
Other	25	12	6	--	221	205	228	225	248	276	281	298								
Total	1,425	1,440	1,280	1,452	1,519	1,274	1,223	1,163	1,157	1,161	1,088	1,112	1,078	1,365	1,316	1,311	1,192	1,046	1,024	901
Nonionics																				
Carboxylic acid amides	56	52	56	56	59	60	52	58	53	53	58	63								
Carboxylic acid esters	191	182	159	210	190	194	182	154	145	143	126	121								
Ethers	617	640	512	568	585	533	552	523	483	492	344	337	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Total	868	877	728	833	834	787	786	736	682	689	533	523	492	434	395	389	349	322	314	274
Cationic	204	178	159	108	207	183	167	155	140	140	123	127	123	96	75	59	36	31	34	26
Amphoteric	17	17	14	19	20	14	10	8	8	8	7	5	5	5	3	59	7	31	34	2
Total	2,515	2,512	2,182	2,502	2,580	2,258	2,186	2,061	1,988	1,998	1,750	1,766	1,698	1,900	1,790	1,758	1,583	1,399	1,372	1,203

N/A - not available.

(X) There was a change in the classification system that makes disaggregation difficult and inaccurate.

SOURCE: U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

TABLE 5

U.S. PRICES OF SURFACTANTS
(dollars per pound)

	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Anionics																				
Sulfonates	.16	.15	.15	.13	N/A	.10	.10	.10	.11	.10	.09	.09								
Carboxylic acids	.38	.37	.38	.37	N/A	.35	.63	.34	.35	.28	N/A	N/A								
Sulfates	.45	.39	.39	.37	.26	.23	.25	.23	.21	.21	N/A	N/A	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Phosphates & poly-phosphates	.71	.73	.72	.59	.49	.45	.46	.51	.49	.47	.52	.53								
Other	.36	.38	.37	N/A	.23	.19	.17	.16	.15	.15	.15	.14								
Total	.24	.22	.22	.20	.15	.15	.15	.15	.14	.14	.13	.12	.14	.14	.14	.15	.16	.16	.16	.16
Nonionics																				
Carboxylic acid amides	.55	.52	.52	.64	.34	.30	.31	.29	.28	.30	.26	.30								
Carboxylic acid esters	.60	.58	.60	.51	.35	.29	.30	.32	.31	.30	.32	.33								
Ethers	.37	.35	.36	.30	.20	.19	.17	.15	.15	.14	.17	.18	(X)	(X)	(X)	(X)	(X)	(X)	(X)	(X)
Other	1.22	1.21	N/A	N/A	N/A	N/A	N/A	1.09	.94	1.03	.46	.87								
Total	.44	.41	.42	.38	.24	.22	.21	.20	.20	.19	.22	.23	.23	.35	.26	.26	.27	.28	.28	.26
Cationic	.69	.69	.69	1.15	.43	.39	.40	.41	.41	.41	.39	.40	.41	.45	.47	.50	.58	.63	.52	.56
Amphoteric	1.08	1.13	.94	.91	.67	.67	.68	.72	.64	.59	.62	.66	.60	.61	.65	.50	.60	.63	.52	.49
TOTAL	.35	.33	.33	.30	.21	.20	.19	.19	.19	.18	.18	.18	.18	.18	.18	.18	.60	.20	.20	.20

N/A - not available.

(X) There was a change in the classification system that makes disaggregation difficult and inaccurate.

SOURCE: U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

TABLE 6

LAB PRODUCTION AND DEMAND DATA

Supply

Producer	Capacity - 1979 (million lbs.)
Conoco	240
Monsanto	225
Union Carbide	140
Witco	40
Total	645

Demand

1978: 524 million lbs.
1979: 530 million lbs.
1983: 560 million lbs.

Growth in Demand

1968-1978: - .1% annually.
1979-1983: - 1.5% annually.

Uses

LAS:	90%
Exports:	9%
Other:	1%

Source: Chemical Marketing Reporter, May 28, 1979.

TABLE 7

FOREIGN TRADE OF SURFACTANTS

	1970	1971	1972	1973	1974	1975	1976	1977
Exports								
Million Pounds	134	142	151	174	198	151	163	157
% of Production	3.4	3.7	3.7	4.0	4.2	3.5	3.4	3.3
Imports								
Million Pounds	74	56	42	62	73	75	88	98
% of Consumption	1.7	1.5	1.1	1.5	1.6	1.8	1.9	2.1

Source: Synthetic Organic Chemicals.

Diamond Shamrock, ICI United States, and Stepan are the three large companies selling their surfactants to other firms. Smaller companies in this group include Alcolac, Emery Industries, Glyco, Miranol, Henkel, Lonza, Millmaster Onyx, Mona, and Quaker Chemical.

Companies using most of their production captively include Proctor and Gamble, Lever Brothers, and Colgate-Palmolive, the three synthetic detergent giants. Witco Chemical also uses surfactants in its private label detergents. About 50 percent of total surfactant production is captively consumed.[14]

FOREIGN TRADE

Between 1970 and 1977 estimated annual U.S. exports of surfactants increased from 134 million pounds valued at $41 million to 157 million pounds valued at $83 million (see Table 6). Exports ranged from 3.3 percent to 4.2 percent of total quantity.[15] Principal export markets were Canada, Japan, Holland, Belgium, Great Britain, France, and other European countries. Nonionics were the largest export group, valued at $21 million.

The volume of exports is not expected to exceed 173 million pounds in 1982 and will probably continue to grow erratically. High shipping costs and foreign production levels should limit export growth

Imports in 1977 totaled 98 million pounds, an increase of 11 percent over 1976. This represented 2.1 percent of U.S. consumption.

Imports consist mainly of non-benzenoid surfactants, including 28.5 million pounds of lignosulfonates. Total imports are expected to reach 150 million pounds by 1982.

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[14] Meegan, Kline Guide. p. 166.

[15] U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

INNOVATION

The surfactant industry appears to have shown a great deal of innovation in the past and will probably continue to do so. Many significant new uses have been found for surfactants in the areas of oil processing, phosphate ester anionics, cosmetics, dry cleaning, emulsion polymerization, powdered and liquid detergents, and fabric softeners. Currently, unknown uses may require totally new surfactants. There is still much room for innovation in detergent surfactants, i.e., a completely biodegradable replacement must be found for LAS. We predict that the use of nonionics will continue to grow as detergent phosphate levels are decreased, and, as energy costs rise, there will be pressure to develop surfactants that work well in cold water.

ICF conducted an analysis of new chemicals that are introduced for commercial purposes. From a sample of 1978 through 1979 issues of Chemical Purchasing, 151 new chemicals were identified. Of these, ten were surfactants. Only one of these surfactants had been introduced by a major producer (Stepan). Also, five new surfactants were geared toward uses other than synthetic detergents, and three, introduced by Hodag Chemical Corporation, were for use in food processing.

This analysis is not conclusive for it is limited by a small sample size, a relatively short time span, and publishing considerations. However, it does suggest that a substantial amount of innovation is occurring, and that much of this is being done in relatively small firms.

Fatty Acids and Glycerin

FATTY ACIDS AND GLYCERIN

FATTY ACIDS

Fatty acids are carboxylic acids with long, straight hydrocarbon chains. They are one of two byproducts from the hydrolysis of natural fats; the other byproduct is glycerin.

Fats and oils are usually combinations of oleic, palmitic, and stearic fatty acids with glycerin. Oleic acid is the principal acid in olive and cottonseed oils, and palmitic and stearic acids are the major acids in tallow. Tall oil fatty acids occur freely in crude tall oil,[1] so the pulp and paper industry, which produces crude tall oil, also produces some fatty acids as a byproduct.

Fatty acids can also be produced synthetically from petroleum derivatives. This source is widely used in Europe where there is a shortage of natural oil[2] supplies, although some synthetic fatty acids are also produced in this country. The rising costs of natural oils, uncertainty about droughts and storms, and political considerations have motivated the industry to look for other sources. Because of soaring petroleum prices, synthetics are not presently viable; however, there are two exceptions. High coconut oil prices and a shortage of alternative supplies have resulted in the continued popularity of short chain (C_{5-10}) acids found in oil despite rising oil prices. The second exception is the group of branched chain fatty acids, which usually do not occur naturally.

In 1978 the industry produced 1,351.2 million pounds of fatty acids (see Table 1), and captive consumption and sales totaled 1.411 billion pounds (Table 2), about 21.4 percent of which was captively consumed. Domestic shipments were $1,066.4 million (Table 3), and exports were $82.2 million (Table 4).

Between 1967 and 1978 production grew at an annual rate of 4.15 percent. Since 1975 production has grown at a 11.8 percent rate. Continued growth is expected at between 2.5 and 4 percent. C.H. Kline Company expects shipments to reach $390 million in 1985, which represents a three percent growth rate.

Fatty acids are used in many markets. In 1977, rubber compounding accounted for the largest share, 10.8 percent. Use in emulsion polymerization, food, plastics, cosmetics, household detergents, soaps, ozonolysis, polishes, and speciality household cleaners had a total of 61.6 percent (see breakdown in Table 5). Other uses accounted for 27.6 percent. Exports accounted for only 6.7 percent of production but were over 10 percent of the total value of shipments (see Table 6). Imports were negligible.

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[1] Tall oil comes from pine wood.

[2] In this report, oil refers to vegetable and animal oils, not petroleum.

Tall oil, a pine wood derivative, is the most important fatty acid group, accounting for 29 percent of total production. In 1975 tall oil fatty acids were used in intermediate chemicals (48 percent), protective coatings (23 percent), and soaps, detergents, and disinfectants. (12 percent). Approximately 30 million pounds were exported Other unsaturated[3] oils accounted for 29 percent of total production; saturated oils accounted for the rest. Oleic acid is used primarily in surfactants. Stearic acid, accounting for nine percent of production, is used mainly in rubber compounding, but is also used in surfactants, plasticizers, metallic soaps, and cosmetics. Lauric acid, derived from coconut oil, is used in specialty detergents, plasticizers, cosmetics, and high-performance synthetic lubricants, the production of which is growing very rapidly. Fatty acids are also employed in textiles, paints, mining, leather, and metal work.

Many fatty acids are upgraded through esterification, polymerization, oxidation, and hydrogenolysis. Fatty acids are easily transformed into fatty alcohols, amides, amines, and nitriles, and can also be sulfonated and chlorinated

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[3] Saturation refers to the number of valence bonds, (i.e., carbon atoms) in a fatty acid.

TABLE 1

FATTY ACID PRODUCTION, 1974 - 1978
(millions of pounds)

Saturated Fatty Acids	1974	1975	1976	1977	1978
1. Stearic acid--40-50% stearic content	115.4	94.4	123.5	123.9	127.2
2a. Hydrogenated fatty acids having a maximum titer of 60°C and a minimum I.V. of 5	98.5	86.3	103.1	102.3	98.1
2b. Hydrogenated fatty acids having a minimum titer of 57°C and a maximum I.V. under 5	165.7	99.5	126.8	142.8	158.5
2c. Hydrogenated fatty acids having a minimum stearic content of 70%.	31.2	27.2	30.8	30.4	32.3
3. High palmitic-over 60% palmitic, I.V. maximum 12	14.6	8.3	8.3	11.5	14.7
4. Hydrogenated fish fatty acids,	9.1	5.1	7.3	7.0	6.5
5. Coconut-type acids I.V. 5 or more including palm kernel and babassu, hydrogenated coconut acid	61.9	58.9	69.3	79.4	88.8
6a. Fractionated short-chain acids C_{10} or lower including capric	14.8	14.1	18.4	19.1	18.6
6b. Fractionated short-chain fatty acids, lauric and for myristic content of 55% or more.	17.8	15.1	16.2	17.4	16.8
TOTAL SATURATED	529.0	409.0	503.6	533.8	561.4
Unsaturated Fatty Acids					
7. Oleic Acid	165.8	118.1	154.6	142.4	158.3
8. Animal fatty acids other than oleic--I.V. 26-80	68.2	113.3	135.9	157.6	156.3
9. Vegetable or marine fatty acids I.V. maximum 115	1.6	.5	9.5	3.5	0.1
10. Unsaturated fatty acids--I.V. 116-130	16.4	19.3	17.4	54.7	57.0
11. Unsaturated fatty acids--I.V. over 130	27.9	12.2	21.4	27.8	24.2
TOTAL UNSATURATED	279.9	263.5	338.7	385.9	396.1
12. Tall oil fatty acids--containing less than 2% rosin acids and more than 95% fatty acids	207.6	149.6	201.0	181.0	191.7
13. Tall oil fatty acids--containing 2% or more rosin acids	155.6	143.6	172.4	178.2	202.1
GRAND TOTAL	1172.1	966.1	1215.7	1278.9	1351.2

Source: Fatty Acid Products' Council, Fatty Acid Production, Disposition and Stocks Census (Monthly); and Pulp Chemicals Association (provided tall oil fatty acid statistics).

NOTE: Titer is the solidification point of the fatty acids which have been liberated from fat by hydrolysis (Condensed Chemical Dictionary, 1971). I.V. is iodine value.

TABLE 2
FATTY ACID DISPOSITION, 1974 - 1978
(millions of pounds)

Saturated Fatty Acids	1974	1975	1976	1977	1978
1. Stearic acid--40-50% stearic content.	114.0	128.2	138.4	142.6	146.2
2a. Hydrogenated fatty acids having a maximum titer of 60°C and a minimum I.V. of 5	96.8	88.6	103.9	102.9	100.5
2b. Hydrogenated fatty acids having a minimum titer of 57°C and a maximum I.C. under 5	162.5	124.8	147.0	165.0	188.1
2c. Hydrogenated fatty acids having a minimum stearic content of 70%	29.8	30.4	33.0	32.5	33.8
3. High palmitic-over 60% palmitic, I.V. maximum 12	13.6	7.9	9.8	12.4	14.4
4. Hydrogenated fish and marine mammal fatty acids	8.7	6.7	7.0	7.2	6.9
5. Coconut-type acids I.V. 5 or over, including plam kernel and babassu, hydrogenated coconut acid	61.2	59.9	71.9	82.0	90.1
6a. Fractioned short-chain acids, C_{10} or lower including capric	15.3	14.0	18.5	19.8	18.1
6b. Fractionated short-chain fatty acids, lauric and for myristic content of 55% or more	16.8	15.3	17.7	19.6	17.6
Unsaturated Fatty Acids					
7. Oleic Acid (red oil)	163.8	121.9	157.8	149.6	160.9
8. Animal fatty acids other than oleic I.V. 26-80	67.3	130.4	157.9	175.6	162.8
9. Vegetable or marine fatty acids I.V. maximum 115	1.6	0.8	9.4	3.5	0.4
10. Unsaturated fatty acids--I.V. 116-130	15.7	19.0	18.6	57.8	56.3
11. Unsaturated fatty acids--I.V. over 130	27.3	12.5	21.7	29.0	24.6
12. Tall Oil fatty acids--containing less than 2% rosin acids and more than 95% fatty acids	202.3	148.1	203.5	178.0	189.6
13. Tall Oil fatty acids--containing 2% or more rosin acids	156.6	133.3	183.9	177.1	200.8
TOTAL	1152.3	1042.1	1300.0	1354.9	1411.1

Source: Fatty Acids Producers' Council, Fatty Acid Production, Disposition & Stocks Census (Monthly); and Pulp Chemicals Association (provided tall oil fatty acid statistics).

Note: Totals may not agree exactly with those shown due to independent rounding of figures. I.V. is iodine value.

TABLE 3
DOMESTIC SHIPMENTS OF FATTY ACIDS, 1974 - 1978
(millions of pounds)

Saturated Fatty Acids	1974	1975	1976	1977	1978
1. Stearic acid--40-50% stearic content	82.7	71.2	92.8	96.0	94.5
2a. Hydrogenated fatty acids having a minimum titer of 60°C and a minimum I.V. of 5	94.7	85.5	101.9	100.8	99.0
2b. Hydrogenated fatty acids having a minimum titer of 57°C and a maximum I.V. under 5	92.3	58.4	96.4	99.7	115.3
2c. Hydrogenated fatty acids having a minimum stearic content of 70%	24.5	24.3	25.0	23.6	25.4
3. High Palmitic-over 60% of palmitic, I.V. maximum 12	6.3	3.2	5.2	6.3	7.1
4. Hydrogenated fish and marine mammal fatty acids	8.4	5.7	5.9	6.2	5.3
5. Coconut-type acids I.V. 5 or over, including palm kernel and babassu, hydrogenated coconut acid	55.0	45.8	54.0	56.8	61.4
6a. Fractionated short-chain acids, C_{10} or lower including capric	13.8	11.9	16.0	16.5	16.9
6b. Fractionated short-chain fatty acids, lauric and for myristic content of 55% or more	7.8	7.1	12.0	10.1	9.6
Unsaturated Fatty Acids					
7 Oleic Acid (red oil)	95.2	60.5	85.9	90.3	86.4
8. Animal fatty acids other than oleic I.V. 26-80	58.5	99.7	109.9	119.4	119.0
9. Vegetable or marine fatty acids I.V. maximum 115	0.7	0.4	9.1	1.3	0.3
10. Unsaturated fatty acids--I.V. 116-130	12.6	10.8	9.8	39.3	36.1
11. Unsaturated fatty acids--I.V. over 130	26.8	12.1	16.4	26.9	21.1
12. Tall oil fatty acids--containing less than 2% rosin acids and more than 95% fatty acids	179.2	133.4	173.6	155.7	196.6
13. Tall oil fatty acids--containing 2% or more rosin acids	132.9	124.8	163.8	137.8	172.4
TOTAL	891.8	754.7	977.7	986.9	1066.4

Source: Fatty Acids Producers' Council, Fatty Acid Production, Disposition & Stocks Census (Monthly); and Pulp Chemicals Association (provided tall oil fatty acid statistics).

Note: Totals may not agree exactly with those shown due to independent rounding of figures. I.V. is iodine value.

TABLE 4
CAPTIVE CONSUMPTION OF FATTY ACIDS, 1974 - 1978
(millions of pounds)

Saturated Fatty Acids	1974	1975	1976	1977	1978
1. Stearic acid--40-50% stearic content	28.6	55.5	43.5	45.0	49.6
2a. Hydrogenated fatty acids having a maximum titer of [illegible]°C and a minimum I.V. of 5	0.4	1.9	0.6	1.5	0.4
2b. Hydrogenated fatty acids having a minimum titer of 57°C and a maximum I.V. under 5	70.2	63.3	50.2	64.8	72.1
2c. Hydrogenated fatty acids having a minimum stearic content of 70%	5.1	5.9	7.6	8.8	8.3
3. High palmitic-over 60% palmitic, I.V. maximum 12	6.6	4.6	4.4	5.8	7.1
4. Hydrogenated fish and marine mammal fatty acids	0.3	1.0	1.1	0.9	1.5
5. Coconut-type acids I.V. 5 or over, including palm kernel and babassu, hydrogenated coconut acid	6.2	13.9	17.7	25.1	28.4
6a. Fractionated short-chain acids, C_{10} or lower including capric	1.4	0.8	0.8	1.0	1.0
6b. Fractionated short-chain fatty acids lauric and for myristic content of 55% or more	8.8	8.1	5.5	9.4	7.8
Unsaturated Fatty Acids					
7. Oleic Acid (red oil)	64.7	57.8	69.2	55.6	69.6
8. Animal fatty acids other than oleic I.V. 26-80	8.7	30.4	47.8	53.2	34.8
9. Vegetable or marine fatty cids I.V. maximum 115	0.9	0.4	8.4	2.2	
0.1					
10. Unsaturated fatty acids--I.V. 116-130	3.1	8.3	8.9	7.8	8.1
11. Unsaturated fatty acids--I.V. over 130	--	--	0.2	0.9	1.1
12. Tall oil fatty acids--containing less than 2% rosin acids and more than 95% fatty acids	n.a.	n.a.	n.a.	n.a.	n.a.
13. Tall oil fatty acids--containing 2% or more rosin acids	n.a.	n.a.	n.a.	n.a.	n.a.
TOTAL	205.0	251.9	265.9	282.2	289.8

Source: Fatty Acids Producers' Council, Fatty Acid Production, Disposition & Stocks Census (Monthly); and Pulp Chemicals Association (provided tall oil fatty acid statistics).

n.a. - Not Available.

Note: I.V. is iodine value.

TABLE 5

PERCENT OF FATTY ACID USE BY MARKET: 1977

Market	Percent
Rubber compounding	10.8
Emulsion polymerization	9.9
Food	8.0
Plastics	7.5
Cosmetics	7.0
Household Detergents	7.0
Soaps	6.3
Ozonolysis	6.1
Polishes	5.1
Specialty household cleaners	4.7
Others	27.6
Exports	6.7

Source: "Fatty Acids Use to Increase, Partly because of Plastic Boom," Chemical Marketing Reporter. April 18, 1978.

TABLE 6
FATTY ACID EXPORTS, 1974 - 1978
(millions of pounds)

Saturated Fatty Acids	1974	1975	1976	1977	1978
1. Stearic acid--40-50% stearic content	2.7	1.5	2.1	1.6	2.1
2a. Hydrogenated fatty acids having a maximum titer of 60°C and a minimum I.V. of 5	1.6	1.4	1.3	0.6	1.1
2b. Hydrogenated fatty acids having a minimum titer of 57°C and a maximum I.V. under 5	0.1	3.1	0.4	0.5	0.7
2c. Hydrogenated fatty acids having a minimum stearic content of 70%	0.2	0.1	0.5	0.1	0.2
3. High palmitic-over 60% palmitic, I.V. maximum 12	0.7	0.1	0.2	0.1	0.2
4. Hydrogenated fish and marine mammal fatty acids	a/	a/	a/	0.05	0.1
5. Coconut-type acids I.V. 5 or over, including palm kernel and bassu, and hydrogenated coconut acid	0.05	0.2	0.3	0.2	0.2
6a. Fractionated short-chain acids, C_{10} or lower including capric	0.09	0.1	0.2	0.2	0.3
6b. Fractionated short-chain fatty acids, lauric and for myristic content of 55% or more	0.1	0.1	0.2	0.2	0.3
Unsaturated Fatty Acids					
7. Oleic Acid (red oil)	3.1	3.6	2.7	3.8	4.9
8. Animal fatty acids other than oleic I.V. 26-30	0.06	0.3	0.2	3.0	9.0
9. Vegetable or marine fatty acids I.V. maximum 115	--	--	a/	a/	--
10. Unsaturated fatty acids--I.V. 116-130	0.04	0.05	a/	10.7	12.0
11. Unsaturated fatty acids--I.V. over 130	0.6	0.4	5.1	1.1	2.4
12. Tall oil fatty acids--containing less than 2% rosin acids and more than 95% fatty acids.	27.2	14.8	29.9	22.7	20.3
13. Tall oil fatty acids--containing 2% or more rosin acids	23.7	8.5	20.1	39.7	28.5
TOTAL	60.2	35.6	65.5	86.7	82.2

Source: Fatty Acids Producers' Council, Fatty Acid Production, Disposition & Stocks Census (Monthly); and Pulp Chemicals Association (provided tall oil fatty acid statistics).

a/ Less than 10,000 pounds.

Note: I.V. is iodine value.

There are about 20 companies manufacturing fatty acids. The largest producers are Armak, Ashland Chemical, Emery Industries, Hercules, Humko, Sheffield Chemical, and Union Camp. Other companies include Baker Castor Oil, Darling, General Mills, Glyco, and Millmaster Onyx. Nearly all of these companies also make fatty acid derivatives.

The fatty acid industry should not be affected by a premanufacturing notification requirement (PMN). All natural fatty acids come from animal and vegetable fats so there seem to be no problems with regard to toxicity or innovation. The synthetic fatty acids are not toxic and it appears that not enough of them are being developed to consider this an innovative segment. Rising petroleum prices continue to seriously limit this market.

GLYCERIN

Glycerin is the other byproduct of the hydrolysis of natural fats. It has many desirable characteristics, giving it many applications. Glycerin absorbs and retains moisture up to 50 percent of its volume. It has strong solvent powers but is itself insoluble in chloroform and gasoline. It is clear, colorless, viscous, very stable, and noncorrosive. It also has strong preservative powers.

Because of all these qualities, glycerin is used in more than 25 industries. These include: adhesives and cements, cleaners and polishes, electrical equipment, explosives, leathers, lubricants, metals, packaging materials, paper photography, plastics, printing and lithography, paints and protective coatings, rubber, textiles and dyes, tobacco, glass, agriculture, cosmetics, beverages, foods, medicine and surgery, dentistry, pharmaceuticals, veterinary medicine, and optometry (see Table 7).

TABLE 7

GLYCERIN END USE PATTERN

Derivative	1979 Estimate Percent	1978 Estimate Percent
Drugs and Cosmetics	21	22
Food and Beverage	17	15
Alkyd Resins	15	15
Tobacco	9	10
Cellophane	7	5
Polyether Polyols	8	8
Explosives	2	2
Exports	15	15
Miscellaneous	6	8

Source: Mannsville Chemical Products, "Chemical Brief", Chemical Age, March 1979.

The supply of natural glycerin is determined by fatty acid production. Since demand is greater than supply, there is a market for more expensive synthetic glycerin.[4] As demand changes, synthetic glycerin production changes. The existing market causes extreme volatility in synthetic production and tight price competition. In 1977 synthetic glycerin represented 45 percent of the total market. In 1978, because of decreasing overall glycerin demand, synthetic glycerin represented only 32 percent of the total market. Prices decreased from $.48 to $.47 per pound (see Table 8).

Over the last few years domestic demand for glycerin has declined. Glycerin is used as a plasticizer in cellophane processing; this application historically accounted for about 15 percent of glycerin demand. Recently, however, it has dropped to five percent, as cellophane production has severely decreased. The demand for glycerin in the explosives industry has also severely decreased, and went from five percent to two percent of glycerin demand. The use of alkyd resins, used in paints, has shown slow growth as paint formulations use less glycerin than in the past.

Between 1960 and 1970 domestic demand decreased 10 percent. Nevertheless, exports grew 270 percent, allowing overall production to increase at one or two percent over the 10 year period. In the 1970s, however, domestic demand was static while imports rapidly increased,[5] and this caused a drop in U.S. production.

Production of natural glycerin was estimated at more than 200 million pounds for 1978.[6] The average price was $.47 per pound, and in 1979 prices rose to $.58 because of lower domestic production. During the next few years, production is expected to decrease by one or two percent annually.

The major producers of natural glycerin are the major manufacturers of soaps and fatty acids. These include Armak, Proctor and Gamble, Colgate-Palmolive, Emery, Humko, Kraftco, Lever Brothers, Pacific Soap, Swift, and Union Camp.

Because it is non-toxic and has shown no innovation, glycerin will not be affected by a PMN. It may find some new uses, but its nontoxicity should make a PMN a mere formality.

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[4] Synthetic glycerin is classified in SIC 28695.

[5] Imports have since ceased.

[6] Mannsville Chemical Products, Chemical Products Synopsis, October 1979.

TABLE 8

AVERAGE PRICES RANGE-GLYCERINE-SYNTHETIC-99.6%
CENTS PER POUND-DELIVERED-BULK-EASTERN

	1960	1965	1970	1974	1975	1976	1977	1978	1979	1980
Trade List Prices	29 1/4	23	20 1/4	22 1/2-50	48-50	46-48	50-50 1/4	51 1/4-49	49-58	60-62
Average Sales Price	27		19	42	48	47	48	47		

ESTIMATED GLYCERINE PRODUCTION:
ALL GRADES-SYNTHETIC AND NATURAL-100% BASIS
(millions of pounds)

	1960	1965	1970	1974	1975	1976	1977	1978	1979	1980	1982	1985
Capacity												
Natural	180	180	165	165	165	165	165	180	180	180		
Synthetic	150	250	360	335	335	335	335	345	345	170		
Production	305	353	336	358	272	325	311	303	350 (Est)			
Demand	285	305	274	296	218	277	286	286	297	250	290	280
Inventory Change			(12)		6	(6)	8	(16)	(8)			
Exports	20	52	74	66	45	58	30	40	58 (Est)			
Imports	15	4		6	1	4	13	7	--			

Source: "Glycerine," Chemical Products Synopsis (a reporting service of Mannsville Chemical Products Co., Cortland, N.Y.), October 1979.

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Soaps and Detergents

SOAPS AND DETERGENTS - INTRODUCTION

INTRODUCTION

Soap and detergent industry shipments were $6.3 billion in 1978 and real annual growth is expected to be 2.7 percent.[1] Soaps, household detergents, and industrial cleaners each have different markets and market structures. The household soap industry is highly concentrated; one product has been the industry leader for decades. Both household soaps and detergents involve a great deal of advertising and a good distribution system. The top three major household detergent producers comprise 83 percent of the industry. One product, in fact, has held more than 25 percent of the market for 25 years. In contrast, industrial cleaners are not concentrated at all. Most products are sold on a regional level and many are custom tailored to specific uses.

Cleaners can also be classified as either synthetic or natural. The natural cleaners, soaps, have been produced for 3000 years; they are derived from vegetable and animal fats. The synthetic detergents were introduced at the beginning of the twentieth century in Germany; they are mixtures of surfactants, builders, and other agents. The two groups are in direct competition with each other, the synthetics having captured most of the cleaning market since the 1930s. Some analysts believe natural soaps are making a comeback because of environmental issues and cost considerations.

SOAPS

Soap is the sodium, potassium or triethanolamine salt of a long chain organic acid. Soaps are primarily made from beef tallow, palm oil, coconut oil, and olive oil.

To have "detergent power", an acid must have more than nine carbons. Technically, any salt of a fatty acid with more than seven carbons is a soap. As the number of carbons is increased, so is the detergency; however, if the soap has more than 18 carbons it is no longer soluble in water. (The more carbons in each chain, the less soluble the soap.) Oleic acid is one of the best soaps because it has the detergent power of a 17-carbon soap, but the solubility of a 12-carbon soap. Soaps of length greater than 17 carbons are used in scouring pads where they need not be soluble.

Soaps were discovered 3000 years ago by the Romans. In 1791 Nicolas LeBlanc used electrolysis to make sodium hydroxide from sodium chloride, thereby making it possible for anyone possessing electrolysis technology to make soap. In the early 1800's, M.E. Chevreul explained the chemistry involved in soap.

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[1] Charles Kline & Company, Household and Personal Care Products Industry, August 1979.

The basis of soap manufacture is the splitting of fat stocks into fatty acids and glycerin. The glycerin is a valuable byproduct (see Fatty Acids). The fatty acids are neutralized by adding an alkaline material, usually sodium hydroxide. Other minor ingredients are added later for added alkalinity, odor, and aging stability.

Soap works well in soft water; but in hard water, it tends to combine with calcium and magnesium ions to form insoluble curds. Because these curds leave residues such as bathtub rings, while synthetic detergents do not, synthetic detergents have captured the cleaning industry. Even though synthetics tend to degrease and thereby, dry skin, the cleansing bar industry has seen the entry of some synthetics in combination with natural soaps.

According to the Census of Manufactures, soap and detergent shipments in 1977 were valued at $4,987 million. Industrial and institutional products accounted for $979 million of this value, and household soap products accounted for $710 million (see Table 1). This incidates that soaps represent 14.2 percent of all shipments and 17.7 percent of the household market of SIC 2841 (soaps and other detergents, except specialty cleaners), but Charles Kline & Co. estimates that soap has less than five percent of the cleaning market. The difference in estimates is caused by ambiguities in the classification systems used For soap as defined in this report, the Kline figure is a better estimate.

The two major cleansing bar manufacturers are Proctor & Gamble (Ivory, Coast, Safeguard, Zest, Camay) and Armour-Dial (Dial, Tone). Ivory has the most unit sales, but Armour-Dial maintains that Dial has the most dollar sales. Other large manufacturers are Lever Brothers (Caress, Dove, Lifebouy, Lux, Phase III), Colgate-Palmolive (Irish Spring, Cashmere Bouquet), and Andrew Jergens (Jergens, Gentle Touch). Other major products that contain soap are Brillo scouring pads and some liquid dishwashing lotions. Although the market for the industrial applications of soaps is more diversified than that for synthetic detergents, it follows the same marketing patterns (see Synthetic Detergents). Both markets depend heavily on distribution outlets and advertising, for example.

We believe there is no new chemical innovation in the natural soap industry. Any innovation at all is process innovation. Thus, this industry probably does not warrant further investigation.

Synthetic fatty acids have been developed for use in soaps, and it is possible that new ones may be developed. However, these synthetics are not dangerous and it appears that recently they have not experienced much innovation.

Finally, any soaps containing ingredients other than neutralized fatty acids (this includes almost all cleansing bars) are covered by FDA.

SYNTHETIC DETERGENTS

A synthetic detergent is a mixture of surfactants, builders, bleaching agents, corrosion inhibitors, and other agents used to clean surfaces.

TABLE 1

SOAPS AND OTHER DETERGENTS: VALUE OF SHIPMENTS

(millions of dollars)

	1972	1977	Increase
Total	2,852	4,987	75%
Soaps and Detergents			
Non-Household	653	979	49%
Detergents, Household	1,634	3,807	72%
Synthetic Organic Detergents, Dry			
Light-Duty	79	130	65%
Heavy-Duty (Phosphate)	808	(D)	
Heavy-Duty (Phosphate-Free)	45	499	1014%
Hard-Surface Cleaners	2	12	500%
Synthetic Detergents, Liquid			
Light-Duty	299	483	62%
Heavy-Duty (Phosphate)	(D)	(D)	
Heavy-Duty (Phosphate-Free)	(D)	147	
Pre-Soaks	52	95	83%
Soap, Household	412	710	72%
Toilet Soap	339	613	81%

(D) Withheld

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

Detergents are used to clean textiles, cooking and eating utensils, walls and floors, and metals. They may also be used for human cleansing, and may appear in powder, liquid, tablet, or gel form.

Components

Surfactants are the active component in all detergents. Because they work much better in soft water, builders are used to soften water. Builders prevent the metal ions in hard water, mainly calcium and magnesium, from combining with either surfactants or dirt particles; they also help disperse dirt, provide added and buffered alkalinity, and kill microorganisms. Examples of builders are the condensed polyphospates, STP (also called STPP), tetrasodium pyrophosphate, sodium carbonate, NTA. tetrasodium ethylenediamene tetraacetate (EDTA), and the polycarboxylates.

Bleaches are used to whiten surfaces. There are two types of bleaches in use: Hypochlorites, which include potassium dichloroisocyanurate (KDCC) and chlorinated trisodium phosphate, are the more powerful of the two. The peroxygens such as sodium perborate however are used more often. All detergents containing bleach are in solid form because the liquid bleach solutions are too unstable. Bleaches are used in scouring pads, automatic dishwashing detergents, commercial sanitation, and textile cleaning.

Corrosion inhibiters prevent the corrosion of washing machines and fine china. They are soluble silicates with varying ratios of SiO_2 and Na_2O. They also contribute to detergency because of their alkalinity.

Sudsing modifiers alter the foaming and sudsing properties of a detergent. Mono- and diethanol amides of C_{10-16} fatty acids increase sudsing, and long chain (C_{16-22}) fatty acids and ethoxylated fatty alcohols decrease sudsing.

Fluorescent whitening agents, also called FWA, are fluorescers, brighteners, and optical bleaches. They increase the "brightness" of textiles by absorbing incident light in the ultraviolet region and re-emitting part of it as visible light, generally in the blue region of the visible spectrum. They are organic chromophores modified with an organic substituent to make it attracted to the textile involved. Fluorescent whitening agents are derived from sulfonated triazinylstilbenes, and those for organic fibers differ from those for synthetic fibers. The brighteners are usually incorporated into synthetic fibers when the fibers are produced.

Enzymes loosen soils and stains that have protein and carbohydrate parts, including body soils and food, grass, and blood stains. The commonly used enzymes (proteolytic and amylolytic enzymes) are derived from fermentation cultures of specific strains of ubiquitous bacteria. Research over a long period of time was required to find enzymes that could react at high temperatures. Addition of enzymes to the industry is considered by many to be the most significant advance in detergent technology since the introduction of synthetic detergents.

Anti-redisposition agents help disperse dirt into the liquid solution and prevent it from being redeposited onto the clean surface. Examples include carboxymethyl cellulose and polyvinyl alcohol.

Other components facilitate production or add to product acceptability. Hydrotropes, such as xylene sulfonate, increase surfactant solubility and detergent shelf life. Colors and perfumes are added to improve product appearance.

History

The first synthetic detergents, short chain alkyl napthalene sulfonates, were produced in Germany during World War I because animal fats were being diverted to other uses. Long chain alcohol sulfates were introduced in the 1920s and early 1930s. Long chain alkyl aryl sulfonates were also introduced in the 1930s, and by the end of World War II, had replaced alcohol sulfates (see Surfactants). Companies began to produce detergent formulations from these compounds between 1950 and 1955, which led to the explosive growth of phosphate builders.

In the early 1960s consumers became concerned about the environment. The branched alkyl sulfonates in use at the time were not biodegradable, so linear alkyl sulfanates (LAS) replaced them. However, many environmentalists felt that high phosphate levels in rivers and lakes were causing dangerous levels of algae. This effect was "entrophic", meaning that an increase in mineral and organic nutrients was depleting the waters' dissolved oxygen, and thereby establishing an environment that favors plant over animal life. Although it was not clear that detergents were the major source of the problem, many areas, especially in the Great Lakes region, banned phosphates in detergents, and federal agencies and detergent manufacturers arranged for the voluntary reduction of phosphate levels. It is still questionable if lower phosphate levels in detergents have reduced phosphate levels in our water systems.

Alternatives to phosphate builders that have been tried are zeolites (Proctor & Gamble), Builder M (Monsanto), NTA, carboxymethyloxysuccinate (CMOS) (Lever Bros.), and citric acid. Zeolites are not as effective as phosphates and NTA may be as harmful. Because none of these chemicals presently have the production capacity to replace phosphates, this is an area with potential for innovation.

The latest innovations have been the addition of brighteners (which are losing popularity) and enzymes. Enzymes may be dangerous if workers are constantly exposed to them, but they are harmless in household applications.

Detergent Uses

The largest use of detergents commercially is in textile cleaning. Since World War II, synthetics have replaced soaps in this industry, and soaps now have less than 5 percent of the market. Most detergents (80-90 percent) are powdered, but liquids are gaining popularity. Ten to 20 percent of a detergent's bulk is surfactant, 30 to 60 percent are builders, and 5 to 10 percent are sodium silicates. The rest of the bulk is provided by inconsequential components. Presoaks usually contain less surfactants and more enzymes, builders, and bleach. Heavy-duty laundry detergents contain high levels of builders.

The second largest use is in hard surface cleaners, which can be broken up into: automatic and hand dishwashing detergents; floor and wall cleaners; and scouring pads. Except for automatic dishwashing detergents, these contain a relatively large concentration of sudsing agents.

Hand dishwashing detergents usually come in liquid form. In comparison to powders, liquids offer superior ease and convenience, are better suited to the surfactant type and level used in hand dishwashing, and require no builders. Dishwashing liquids are 25 to 45 percent anionic surfactants; the remaining ingredients are solvents. hydrotropes, buffers. colors, perfumes, and water. The surfactants usually used are LAS, alkyl sulfates, alkyl polyethoxy sulfates. di- or mono-ethenol fatty acid amides, alkyl glyceryl ether sulfonates, and alkyl dimethylamine oxides. These surfactants have shorter chains than those used in detergents.

Automatic dishwashing detergents require low sudsing to avoid overflows, complete rinsing to avoid residual deposits, and complete chelating. Chelating is the process of neutralizing mineral ions in hard water. Automatic dishwashing detergents require a low level of nonionic surfactant, usually polyoxyethylene or polyoxypropylene condensate, a low level of bleach, a high level of builder (usually STP or sodium carbonate), and a moderate to high level of alkalinity in auxiliary sources. All automatic dishwashing detergents are powders to accommodate dishwashing machine design.

Abrasive cleaners have a high level of abrasive, usually silica flour, a low level of bleach, and a low level of surfactant which serves as a wetting agent and helps remove stains.

Large area cleaners come in both liquid and solid form. The liquids contain a low level of nonionic and anionic surfactant, a high level of stable, highly soluble builder (usually tetrapotassium pyrophosphate) solvents, hydrotropes, and water. The solids contain very low levels of surfactant (usually LAS), moderate levels of builder (usually STP), and high levels of mild alkalinity (usually trisodium phosphate and mixtures of sodium carbonate and sodium bicarbonate). All large area cleaners require low sudsing.

Personal care products using synthetic detergents include cleansing bars, shampoos, bubble baths, cosmetic cleaners, and toothpaste. The cleansing bar market is still dominated by natural soaps but some synthetic soaps have appeared. Unfortunately, the synthetics degrease skin, although some mixtures of natural and synthetic detergents have been successful in the market. Surfactants sometimes added are alkyl sulfates, alkyl glyceryl ether sulfonates. alkyl esters of sodium isethionate. and alkyl amides of N-methyl tauride. Other personal care products are in SIC 2842 and are covered by FDA regulations.

Industrial and institutional products are analogous to household products but are more powerful, more specialized and are packaged differently. Applications unique to certain industries and institutions include yarn cleaning, metal cleaning, and surgical equipment.

Manufacturing Process

The most sophisticated method for producing detergents is called spray drying. The first step is sulfation and/or sulfonation of anionic surfactant intermediates (fatty alcohol and/or LAB). This is accomplished through the introduction of oleum and intermediates into a special acid-resistant alloy pump which acts as a mixer for raw materials. Reaction heat is reduced by putting the surfactant into a larger mass of recirculating, externally cooled, reaction product just prior to sulfation. Key control variables are:

1) temperature, which must be high enough for pumpable viscosity and rapid reaction, but low enough to avoid charring;

2) the ratio of oleum to surfactant intermediate;

3) mixing efficiency; and

4) reaction time.

The second step is neutralization of the acidity of the surfactant using sodium hydroxide. This forms the sodium surfactant salts present in the final detergent product. Sodium sulfate is also formed from neutralization of excess sulfuric acid, and it passes into the finished product. Heat of reaction is again reduced by mixing the reactants with a larger, externally cooled. recirculating mass of neutralized material. The resultant neutralized surfactant paste is passed through a cooler to a holding tank.

Next, the major detergent ingredients--surfactant paste. builders, and corrosion inhibitors--are mixed together to form a thick paste in a large closed tank containing a worm screw agitator. The tank is mounted on a scale to determine an accurate measurement of each component. The mixer is called a crutcher, and the process crutching. This is usually done in a batch and then poured into a holding tank for continuous operation of the next step.

High pressure pumps deliver paste to the atomizing nozzles of a spray drying tower. Droplets from the nozzles are puffed into granules and dried by hot (600°F) air. Finally, the granules are cooled and the remaining ingredients are added.

A simpler method involves just adding the dry raw materials to heated surfactant. but usually more than one mixing is needed. Liquid and paste detergents are mixed in batches. and may be preceded by sulfation or sulfonation of the surfactant intermediate, or a finished surfactant may be used. The key control factors are temperature, time. agitation rate. and the specific hydrotropes used.

The Industry and Its Relationship to Other Industries

In 1978 sales of household soaps and detergents were estimated at $3 billion and sales of industrial and institutional soaps and detergents were $1.9 billion.[2] In 1977 the industry had 31.900 employees, an increase of one percent from 1972. Leading states in employment were New Jersey, California. Ohio, and Illinois, representing about 40 percent of the total.[3]

The synthetic detergent industry buys all its raw materials from basic chemical companies. The industry sometimes uses surfactant intermediates to make finished surfactants.

The soap and detergent industry has two separate markets, household and industrial. The domestic household detergent market is dominated by Proctor & Gamble (P&G) with 50 percent of the market, and Colgate-Palmolive Co. and Lever Brothers, each with 17 percent. Tide, a P&G product, has had more than 25 percent of the market for 25 years.

Proctor & Gamble's total fiscal 1978 sales were $4.1 billion and net income was $512 million. mostly in household cleansers, food products, toiletries, and disposable paper products. Laundry and cleaning products had sales of $3.19 billion. For 1976, "domestic chemical sales" were estimated at $245 million, $200 million of which was earned by the Industrial Chemicals Division in natural glycerin. fatty acids, fatty alcohols. surfactants (mostly for captive use), and specialty textile chemicals. Sales of industrial cleaning products. estimated at $45 million. are handled by the Industrial and Institutional Sales Departments of the Proctor & Gamble Distributing Co.

Colgate-Palmolive Co. had sales of $4.31 billion and net income of $176 million in 1978. Sales of household and personal care products totaled $2.95 billion. Colgate has increased sales and earnings for 18 consecutive years.

Lever Brothers is the only one of the three dominant firms with over half its sales in the detergent market. It is a subsidiary of Unilever, N.V. of Holland. Its major liquid detergent, Wisk, is the industry leader for liquids.

The other 17 percent of the market is shared by S.C. Johnson, Clorox, Sterling Drug, Amway, American Home Products, Bristol-Myers, Purex, and a number of smaller companies.

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[2] Hamilton C. Carson, "Soaps and Detergents." Household and Personal Products Industry, January 1979.

[3] U.S. Department of Commerce. Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

Distribution and marketing are probably the most important factors in the industry. Also. the large capital investment involved in the spray drying technology appears to limit the number of national distributors. Proctor & Gamble's strength in distribution and marketing and its access to substantial capital appear to be the causes of its large share of the market.

The industrial and institutional cleaning products market has a high degree of competitiveness and firms are mostly regional. Less than 30 companies operate on a national basis and only 14 have domestic sales of $25 million or more. These 14 companies share 50 percent of the market. Chemical Week estimates there are 3,000 firms in the industry.[4] Economics Laboratories, the industry leader, has $400 million in yearly sales and has increased its earnings for 26 consecutive years and its sales for 44 consecutive years.

Large producers with at least $10 million in sales include Airwick, Beatrice Foods, Consolidated Foods, Huntington Laboratories, Merck, Occidental Petroleum. Rochester Germicide. Stauffer Chemical. and U.S. Borax and Chemical. Because of the large number of different surfaces to clean, products tend to be specialized. According to Edward Minklein of Klix Chemical Company,[5] the industry has three types of firms: One type manufactures and processes the product and then sells it directly to end users or intermediate formulators. Alcolac, Stauffer, BASF Wyandotte. and Diamond Shamrock fall into this group. Another type only processes and sells the product. Examples are Oakite. Zep, National Chemsearch, West Chemical. and Economics Laboratory. Finally, some firms merely process the material and let distributors market it. Klix Chemical Company falls into this last group.

Industrial and institutional cleaners are associated with much less advertising and lower distributional and capital expenditures than other products in the detergent industries. Instead, they require a high degree of service. which also acts to make these markets more regional in nature.

Different segments of the detergent industry are growing at different rates. Home laundry products have become a mature industry and will only grow with the population. Also, energy considerations are motivating consumers to do larger loads to save energy and simultaneously use less laundry detergent. Therefore, most forecasters are predicting a 2 to 2.5 percent growth rate. Heavy-duty liquids seem to be growing faster than any other segment.

The use of automatic dishwashing detergents will continue to grow rapidly as more consumers buy dishwashers. In 1977 only 38 percent[6] of all households had dishwashers and their use is expected to grow at a rate of four percent annually.[7] Hand dishwashing liquid is losing its market to the automatic dishwashing powders, and its sales are expected to grow 5.5 percent annually in current dollars.[8] The household specialty products industries rate for the use of automatic dishwashing powders are not yet mature and will continue to grow rapidly.

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[4] Chemical Week, August 22, 1973.

[5] Ibid.

[6] "Detergent Sales Expected to Reach $6.1 Billion by 1985", Soap/Cosmetics/Chemical Specialties, April 1977.

The use of industrial and institutional cleaners has also been rapidly growing, but is expected to slow to about 4 percent annually.[9] The use of acid cleaners, car wash detergents, carpet cleaners, sanitizers, and disinfectants will grow faster, and conventional floor care products use will grow slower than it has in the past.

INNOVATION

The synthetic detergent industry is certainly innovative but it seems that a large percentage of that innovation is geared toward new formulations and better processes. Some work is being done on new surfactants and builders and the ecology issues are unsettled.

After a cursory review. it appears that the detergent producers are performing much of this research themselves and then licensing it to their suppliers. This should be verified, however.

Some producers are experimenting with a plastic surfactant that would replace conventional laundry detergent. Also, some new uses. one of which is fatty acid production, are being introduced into the detergents industry.

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[7] John Whitehead, "Slow Growth Seen for U.S. Detergent Market", Chemical Age, November 23, 1979.

[8] "Detergent Sales." Soap/Cosmetics Chemical Specialties.

[9] Mary K. Meegan, ed., Klin Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 136.

TABLE 2

ECONOMIC INDICATORS FOR SOAPS AND DETERGENTS

	1975	1974	1973	1972	1971	1970	1969	1968
Employees (thousands)	30.0	30.9	32.4	31.5	30.1	30.9	30.8	29.6
Payroll (millions of dollars)	406.3	385.3	371.2	341.6	305.5	283.5	269.8	246.7
Production workers (thousands)	19.3	20.0	20.9	20.4	19.2	19.9	20.5	19.8
Man hours (millions)	38.1	40.5	41.3	40.9	38.0	39.8	40.5	38.8
Wages (millions of dollars)	241.2	228.7	222.0	205.9	178.7	171.6	161.5	150.6
Value added (millions of dollars)	2249.2	2267.4	2011.3	2038.8	1728.1	1647.6	1542.7	1485.9
Cost of materials (millions of dollars)	2383.3	2216.3	1699.4	1373.7	1291.4	1375.3	1346.1	1286.7
Value. industry shipment (millions of dollars)	4675.6	4383.9	3758.7	3394.4	3020.7	2987.3	2888.6	2763.0
New investments (millions of dollars)	107.2	103.5	77.0	90.7	96.2	84.7	48.6	46.0
End of Year Inventory (millions of dollars)	536.0	592.1	379.7	381.7	326.4	317.8	274.7	266.7

Source: U.S. Department of Commerce. Bureau of Census, Annual Survey of Manufacturers (Washington, D.C.: Government Printing Office, various years).

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Elementary Organic Chemicals

ELEMENTARY ORGANIC CHEMICALS SEGMENT SUMMARY

Petroleum Refinery Products
Cyclic Crudes
Gum and Wood Chemicals

Elementary Organic Chemicals are the simple alkanes, olefins and aromatics which can be obtained directly from petroleum, coal, or wood. Although the products can be varied to some extent by making minor adjustments in the production processes, emphasis is always placed on production of the relatively small number of basic compounds which serve as the building blocks for the entire organic chemical industry.

Prior to World War II, the basic chemical building blocks were derived primarily from coal tar, a by-product of coke manufacture. But with the development of the vast Middle East oil fields after World War II, petroleum displaced coal as the primary chemical feedstock. Although the basic chemical building blocks could also be obtained from gum and wood chemicals, in practice they are not. The major types of gum and wood chemicals are turpentine, charcoal, rosin, and tall oil.

Product innovation in this segment appears to be virtually non-existent. But, the huge petroleum price increases of the last ten years have brought about renewed interest in coal-based chemical feedstocks. It seems that such a switch would result in significant process innovation in the chemical industry. However, in light of the intricate oil-based network which has developed over the last thirty years, any conversion from petroleum to coal will be slow. The energy crunch has also renewed interest in biomass-based chemicals, but here again any expansion will be slow.

The production of petroleum refinery products, by far the dominant factor in this segment, is relatively unconcentrated and has changed little over the years. In both 1958 and 1972, the top four firms accounted for 13 percent of the total value of shipments. Petroleum products are produced by almost all major chemical and petroleum companies.

Petroleum Refinery Products

PETROLEUM REFINERY PRODUCTS

DESCRIPTION

SIC code 2911 comprises establishments primarily engaged in the production of gasoline; kerosene; distillate fuel oil; residual fuel oils; lubricants and other products (from crude petroleum); and fractionation products (through straight distillation of crude oil, redistillation of unfinished petroleum derivatives, cracking or other processes).[1]

This category includes common products like kerosene, paraffin wax, and petroleum jelly in addition to less familiar items like butane, butadiene, petroleum, coke, and xylene. All of these products fall under the broad classification of basic organic chemicals, which are distinct from intermediate and end products. Petroleum products are not further altered chemically, but are either formulated with other materials or used by other industries for fabricating products.

In general, petroleum products are commodities produced in relatively large volumes and sold at low prices. In 1976 an estimated 289 billion pounds of organic chemicals were produced, 74 percent of which could be classified as basic and intermediate compounds.[2] Of these, over 54 percent were basic petrochemicals such as benzene, toluene, propylene, ethylene and xylene.[3]

ENGINEERING PROCESS

The chemical composition of crude oil varies widely, especially with respect to hydrocarbon compound content. When underground in its natural state it is at a higher temperature and greater pressure than at the surface. Changes in pressure and temperature that occur during the extraction process release or break down some of the hydrocarbons contained in crude oil.

The hydrocarbons within crude oil can be divided into numerous categorical series according to their chemical properties. The four series that comprise most of the naturally occurring petroleum products are paraffin, isoparaffin, naphthene, and aromatics. Petroleum products are the result of assorted chemical reactions and mixtures of hydrocarbons from all of these series.

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[1] Executive Office of the President, Office of Management and Budget, Standard Industrial Classification, 1972 (Washington, D.C.: Government Printing Office, 1972).

[2] Mary K. Megan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

[3] Forty-four percent were petrochemical intermediates and solvents, and the remainder were gum and wood chemicals and fatty acids.

Petroleum products are often derived through distillation and fractionation processes of crude oil (see Table 1). Roughly 55 percent of the raw materials for basic petrochemicals are byproducts or coproducts of petroleum refining. The remainder is obtained from natural gas feedstocks.[4]

USES

Petroleum products produced in refineries have wide-ranging uses and applications. Kerosene that is distilled from petroleum, for example, is used in rocket and jet fuels as well as in solvents and insecticidal sprays. Paraffin wax is used in household products, and petroleum coke and alkylates are important in chemical products processes (see Tables 1 and 2).

Petroleum products generally form a family of basic building blocks used in the manufacture of other organic products. At one time, benzene, toluene, and xylene were mainly byproducts of coke production for steel, but now these building blocks are obtained primarily from petroleum sources.

INDUSTRY STRUCTURE

Petroleum products are produced by almost all major chemical and petroleum companies. The latter group, with its captive feedstocks for chemical conversion, tends to concentrate only on basic organics that it supplies to producers of end-use chemicals. In contrast, chemical companies produce organics for captive consumption in their own chemical end product operations.

Overall concentration in petroleum refinery products has changed very little since 1958 (see Table 3). In both 1958 and 1972 the four largest companies accounted for 13 percent of the total value of shipments. At a more specific product level, such as gasoline or jet fuel, shares of the market appear to be fairly stable. The two exceptions to this are residual fuel oil (where the four largest companies accounted for 34 percent of shipments in 1954 and 41 percent in 1972) and unfinished oils (where the four largest companies had 39 percent of shipments in 1954 and 55 percent in 1972). If any trend exists, it is toward greater concentration.

Concentration on a product-by-product basis varies considerably. The top four producers of miscellaneous petroleum products, including waxes, held 28 percent of the market while the top four producers of jet fuel captured 52 percent of their market in 1972.

Industry structure has changed markedly since World War II. The industry once depended almost entirely on steel mills and coke ovens as sources for raw materials, but it now relies heavily on petroleum feedstocks.[5]

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[4] Meegan, Kline Guide.

[5] Ibid.

TABLE 1

DERIVATION AND USES OF SELECTED PETROLEUM PRODUCTS

Product	Engineering Process	Uses
Alkylate	Derived from reaction between an isoparaffin and an olefin	As a high-octane blending component of aviation and civilian gasolines.
Asphalt	Mixture of paraffinic and aromatic hydrocarbons and heterocyclic compounds containing sulfur nitrogen and oxygen; occurs in nature or obtained as residue in petroleum refining.	Paving, road-coating, roofing, sealing, special paints; adhesive in electrical laminates and hot-melt compositions; diluent in low-grade rubber products; fluid loss control in hydraulic fracturing of oil wells; medium for radioactive waste disposal; pipeline and underground cable coating; rust-proofing; base for synthetic turf; water-retaining barrier for sandy soils; supporter of rapid bacterial growth in converting petroleum components to protein.
Benzene	a) Hydrodealkylation of toluene or of pyrolysis gasoline b) Transalkylation of toluene by disproportionation reaction c) Catalytic reforming of petroleum d) Fractional distillation of coal tar	Styrene; synthetic detergents; cyclohexane for nylon; aniline; DDT; maleic anhydride; dichlorobenzene; benzene hexachloride; nitrobenzene; diphenyl; insecticides; fumigants; solvent; paint removers; rubber cement· anti-knock gasoline.
1,3 - butadiene	a) Catalytic dehydrogenation of butenes or butane b) Oxidative dehydrogenation of butenes	Principally in styrene-butadien rubber; as starting material for adiponitrile (nylon 66); in latex paints; resins; organic intermediate.
Coke, petroleum	Destructive distillation (carbonization) of petroleum. Petroleum yields coke during cracking process, the formation acting as a catalyst poison	Refractory furnace lining in electrorefining of aluminum and other high-temperature service; electrodes in electrolytic reduction of alumina to aluminum; electrothermal production of phosphorous; silicon carbide, and calcium carbide.
Kerosene	Distilled from petroleum	Rocket and jet engine fuels; domestic heating; solvent; insecticidal sprays, diesel and tractor fuels.
Lubricating grease	Mixture of mineral oil or oils with one or more soaps.	--
Naphtha	Generic term applied to refined, partly refined, or unrefined petroleum products subject to distillation.	Source of gasoline by various cracking processes; special naphthas, petroleum chemicals, especially ethylene.
Naphthenic acid	Gas-oil fraction of petroleum by extraction with caustic soda solution and subsequent acidification	Production of metallic naphthnates for paint driers and cellulose preservatives; solvents; detergents; rubber reclaiming agent.
Paraffin wax	Occurs naturally in crude oil; obtained from high boiling point fractions.	Candles, paper coating; protective sealant for food products, beverages etc.; glass cleaning preparations; hot-melt carpet backing, biodegradable mulch; impregnating matches; lubricants; crayons; surgery; stoppers for acid bottles; electrical insulation; floor polishes; cosmetics; photography; anti-frothing agent in sugar refining; packing tobacco products, protecting rubber products from sun-cracking.
Petrolatum (mineral was, petroleum jelly, mineral jelly)	Fractional distillation of still residues from the steam distillation of paraffin-base petroleum; or from steam-reduced crude oils from which the light fractions have been removed.	Protective dressing and substitute for fats in ointments; lubricating greases; metal polishes; leather grease; rust preventive; perfume extractor; insect repellants; in foods as defoaming agent, lubricant, release agent, protective coating; softener in white or colored rubber compounds.

Source: Gessner G. Howley, ed., The Condensed Chemical Dictionary (8th ed., New York: Van Nostrand Reinhold Company, 1971).

TABLE 2

USES OF OTHER PETROLEUM PRODUCTS

	Percent
Butadiene	
Synthetic elastomers	53.0
Polybutadiene	18 0
Nitrile rubber and neoprene	10.0
Adiponitrile and other	19.0
Ethylene	
Polyethelene	40.0
Ethylene oxide	20 0
Ethylene dichloride	14.0
Ethylbenzene	10.0
Other	16.0
N-paraffins	
Linear Alkylate (major raw material for surfactants)	70.0
Linear primary and secondary alcohols	24.0
Other	6.0
Propylene	
Isopropanol	14.0
Polypropylene	23 0
Acrylonitrile	13.0
Propylene oxide	10.0
Cumene-phenol	24.0
Other	
Toluene	
Gasoline (octane improver)	90.0
Benzene	6.5
Toluene diisocyanate, Benzyl chloride, and other	3.5

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 3

CONCENTRATION IN PETROLEUM REFINERY PRODUCTS

Product Class	Class of Product	Year	Total (million dollars)	Value of Shipments: Percent Accounted for by– 4 largest companies	8 largest companies	20 largest companies	50 largest companies
2911	Petroleum refinery products	1972	$24,772.8	31	56	84	96
		1967	19,248.5	32	57	84	96
		1963	15,557.7	32	55	81	95
		1958	13,889.4	31	54	81	93
29111	Gasoline	1972	13,029.6	31	55	86	98
		1967	9,844.2	33	58	87	98
29112	Jet Fuel	1972	1,371.6	52	74	92	99
		1967	1,100.4	45	63	86	98
29113	Kerosene	1972	372.4	43	64	93	99+
		1967	430.5	34	54	89	99+
29114	Distillate fuel oil	1972	4,407.7	33	58	87	98
		1967	3,305.7	34	58	85	98
		1963	2,896.3	36	59	83	96
		1958	2,490.9	35	59	83	96
		1954	2,064.3	36	59	85	(N/A)
29115	Residual fuel oil	1972	1,107.2	41	60	83	96
		1967	566.1	38	61	83	96
		1963	621.8	35	55	82	96
		1958	817.2	32	56	83	94
		1954	787.8	34	57	84	(N/A)
29116	Liquefied refinery gases (feed stock and other uses)	1972	1,152.9	38	57	89	99+
		19	1,135.7	39	59	86	99+
29117	Lubricating oils and greases, made in refineries (See also code 29920.)	1972	894.8	39	64	98	100
		1967	883.6	43	65	96	99+

TABLE 3 (continued)

CONCENTRATION IN PETROLEUM REFINERY PRODUCTS

Product Class	Class of Product	Year	Total (million dollars)	Value of Shipments — Percent Accounted for by- 4 largest companies	8 largest companies	20 largest companies	50 largest companies
29118	Unfinished oils and lubricating oil base stock	1972	733.7	55	79	98	100
		1967	613.2	56	76	96	99+
		1963	526.2	51	78	94	99+
		1958	440.9	46	74	94	99
		1954	294.9	39	69	93	(N/A)
29119	Asphalt	1972	671.5	43	62	84	98
		1967	424.2	41	58	82	98
		1963	360.5	43	58	81	98
		1958	284.6	39	56	77	96
		1954	221.7	45	63	83	(N/A)
29110	Other finished petroleum products, including waxes	1972	1,031.4	28	48	79	96
		1967	994.9	36	52	77	96

Source: U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

According to the 1977 Census of Manufactures, the total number of establishments in SIC 2911 dropped by 18 percent from 1963 to 1977.

TABLE 4

NUMBER OF ESTABLISHMENTS

Year	Number of Establishments
1977	349
1972	323
1967	437
1963	427

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

SHIPMENTS

The value of shipments of petroleum refining products increased dramatically from 1963 to 1977. Much of the increase came after 1973; the value of shipments percentage increase was 93 percent from 1963 to 1973, and it was roughly twice that, or 188 percent from 1973 to 1977 (See Table 5).

Data on the value of shipments over time for individual SIC 2911 products are not available. Additionally, data on production quantities for all petroleum refining products are somewhat incomplete (census data omit a number of products, and time trend information is often unavailable--see Appendix A). It appears, however, that the large increases in value of shipments are price rather than quantity related. As the price of petroleum has risen sharply from 1974 on, so has the price of petroleum refining byproducts and co-products.

Of the 20 SIC 2911 products with production in quantities reported by the census, eight (kerosene, heavy fuel oil, unfinished oils, naphtha and other oils, lubricating oil petroleum base stocks, petrolatum, special naphthas, and aromatics) showed production quantity increases (see Appendix A). These increases ranged from a high of 70 percent for aromatics (included in this category are benzene, toluene, xylenes, etc.) to a low of six percent for lubricating oil petroleum base stocks.

As the production increases are rather small in terms of quantity, it seems that price increases are the main factor in the growth of shipment values. As Table 6 shows, prices of refined petroleum products exhibited marked increases since 1974.

Value-added figures, obtained from the 1977 Census of Manufactures, appear in Table 7. The value-added between 1968 and 1977 almost tripled.

TABLE 5

PETROLEUM PRODUCTS: VALUES OF SHIPMENTS[a]
(millions of dollars)

Year	Amount
1963	16,498
1964	16,802
1965	17,501
1966	18,759
1967	20,294
1968	21,361
1969	22,486
1970	22,783
1971	24,584
1972	25,921
1973	31,846
1974	54,834
1975	65,254
1976	77,507
1977	91,833

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979)

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[a] Values reflect all shipments made by establishments in SIC 2911. Values in Table 3 reflect shipments of goods in product category 2911.

TABLE 6

PRICE INDEX

REFINED PETROLEUM PRODUCTS

	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1968
Refined Petroleum Products	325.7	314.1	289.2	273.1	242.3	271.4	112.3	106.1	107.9	101.0	98.8
Gasoline	314.7	279.0	261.1	247.7	204.9	257.4	107.7	101.1	102.9	96.1	93.6
Light Distillate	407.0	383.0	325.6	310.5	253.7	328.3	112.1	105.4	106.2	110.8	112.9
Middle Distillate	425.5	396.6	359.0	336.7	299.1	317.9	113.9	109.7	111.6	107.3	105.6
Residual Fuels	517.9	513.0	492.3	451.8	604.4	450.8	161.8	154.3	165.3	83.4	82.2
Lubricating Oil Materials	382.5	333.4	274.3	267.4	276.6	171.6	102.0	100.7	100.0	114.3	114.3
Finished Lubricants	216.0	197.5	180.4	180.7	179.8	131.1	120.0	111.7	109.8	115.6	109.8
Petroleum Wax	295.4	249.4	206.9	183.2	172.0	N/A	N/A	N/A	N/A	87.8	87.8

Note: 1969 figures were not availble from the Department of Commerce.

Source: U.S. Department of Commerce, Wholesale Price Index and Producer Price Index, various years.

TABLE 7

VALUE-ADDED PETROLEUM PRODUCTS

(millions of dollars)

1977	$14,274
1976	11,410
1975	8,927
1974	8,364
1973	6,519
1972	4,595
1971	4,614
1970	4,608
1969	4,950
1968	4,839

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

FOREIGN TRADE

In recent years the petroleum refinery products industry has been characterized by a trade deficit. In 1974 the deficit hit a high of $8.7 billion as imports climbed 171 percent and exports grew at a slower rate of 53 percent from the year before. Despite a 28 percent decline in imports and a modest seven percent increase in exports, the trade deficit in 1975 loomed at $6 billion. In 1976 the deficit was down slightly to $5.9 billion. In 1977 the trend reversed itself as imports grew by 27 ercent and exports by only nine percent, leaving a trade deficit of $7.7 billion (refer to Table 8 for trade values).

Tables 10 and 11 provide a closer look at the composition of petroleum refinery product exports and imports.

INNOVATION

In reference to Table 9 Production Quantities, there are no products listed in 1977 that were not available in 1972. (Although production figures for some categories such as liquefied refinery gases were not available, this does not mean the products were not in existence.)

TABLE 8

PETROLEUM REFINERY PRODUCTS[a]: FOREIGN TRADE

(thousands of dollars)

	Value of Exports	Value of Imports	Balance of Trade
1977	1,120,476	8,823,584	(7,703,108)
1976	1,029,338	6,916,853	(5,887,515)
1975	932,894	6,977,707	(6,044,813)
1974	874,472	9,628,151	(8,753,679)
1973	569,799	3,554,698	(2,984,899)
1965	454,891	955,652	(500,761)

[a] SIC 2911

Sources: U.S. Department of Commerce, U.S. Exports, FT 610, and U.S. Imports, FT 210.

TABLE 9

PETROLEUM PRODUCTS: PRODUCTION QUANTITIES
(millions of barrels)

Product	SIC code	1977 Quantity	1972 Quantity
Gasoline, inc. finished base stocks and blending agents[a]	29111	N/A	2,397
Jet fuel	29112	N/A	311
Kerosene	29113 13	87	81
Light fuel oil	29114	N/A	1,033
No. 4 Type fuel oil	29114 14	23	1,033
Heavy fuel oil	29115	548	337
Liquefied Refinery Gases:			
Ethane and/or Ethylene		68	N/A
Propane and/or Proplylene		120	N/A
Butane and/or Butylene		47	N/A
Other liquefied refinery gases		28	N/A
Unfinished Oils, Naphthenic and Paraffin[b]	29118 13	92	67
Naphtha and other oils for use as petrochemical feedstocks, except for carbon black	29116 16	57	41
Lubricating oil petroleum base stocks for blending, compounding, and grease manufacture[c]	29118, 51, 52 54, 56, 58	34	32
Petroleum	29110 11	3	2
Road oil[d]	29110 31	3	9
Special Naphthas[e]	29110 51	29	18
Aromatics (benzene, Toluene, xylenes, etc.)	29110 54, 56	122	71

TABLE 9 (continued)

PETROLEUM PRODUCTS: PRODUCTION QUANTITIES
(millions of barrels)

Product	SIC code	1977 Quantity	1972 Quantity
Lubricating and similar oil[f] made in petroleum refineries	29117 21	46	50
Lubricating greases made in petroleum refineries	29117 31	1	2

Source: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

[a] Includes all finished gasoline, finished base stocks, and blending agents such as alkylate, polymers (dimer, codimer, etc.), hydropolymers (hydrodimer, hydrocodimer, etc.), cumene, isopetane, neohexane, iso-octane, motor benzol (benzene), and other blending agents derived from petroleum. Excludes natural gasoline derived from natural gas.

[b] Includes such products as cracking stock, unfinished gasoline requiring further distillation, naphtha stocks, slops, wax distillate, and other finished petroleum oils. Excludes lubricating oil base stocks, natural gasoline, and cycle condensates.

[c] Includes light, medium, heavy neutral, and residual stocks.

[d] Represents residual asphaltic oil used for surface treatment of road and highways.

[e] Includes petroleum ether, rubber solvent, mineral spirits (petroleum spirits), varnish makers' and painters' naphtha, high-solvency naphtha, benzol diluent, lacquer diluent, cleaners' naphtha, stoddard solvent, extraction solvents, and other petroleum distillates shipped as solvents.

[f] Includes oils for lubrication purposes and such non-lubrication purposes as transformer oil, hydraulic oil, processing oil, quenching oil, and liquid rust preventative.

TABLE 10

PETROLEUM REFINERY PRODUCTS: VALUE OF EXPORTS
(thousands of dollars)

Description	Product Class	1977	1976	1975	1974	1973	1965
Aviation Gasoline	2911 10 10	961	864	901	752	1,573	6,260
Gasoline, NEC, and Gasoline Blending agent, NEC	2911 10 30	4,080	4,727	2,202	11,350	19,164	18,111
Jet Fuel	2911 20 00	1,915	3,404	3,459	7,637	4,087	621
Kerosene--except Jet Fuel	2911 30 00	448	504	437	525	810	1,275
Distillate Fuel Oils	2911 40 00	420	1,333	1,156	5,518	25,679	15,493
Residual Fuel Oils	2911 50 00	23,448	32,301	43,179	41,232	23,579	33,509
Butane	2911 6E 25	1,345	2,676	5,516	1,328	3,855	N/A
Propane	2911 6E 45	17,596	23,766	22,291	23,388	23,345	N/A
Butadiene Monomer	2911 6E 50	13,638	13,630	11,423	12,783	6,132	N/A
Butylene	2911 6E 61	1,581	1,106	1,997	--	--	N/A
Ethylene	2911 6E 62	9,689	5,745	362	--	--	N/A
Propylene	2911 6E 63	1,059	2,294	2,607	--	--	N/A
Natural Gas Liquids, including LPG, NEC	2911 6E 97	52,638	72,449	72,234	69,748	29,991	27,231
Lubricating Oils and Nonlubricating, Nonfuel oils	2911 70 20	490,226	436,170	426,671	414,405	238,970	218,565
Lubricating Greases	2911 70 40	29,845	26,825	26,063	24,043	15,981	15,650
Petroleum--Partly refined	2911 80 00	--	--	8,277	--	572	2,082
Petroleum--Asphalt	2911 90 00	6,550	7,271	6,222	5,328	2,981	2,827

TABLE 10 (continued)

PETROLEUM REFINERY PRODUCTS: VALUE OF EXPORTS
(thousands of dollars)

Description	Product Class	1977	1976	1975	1974	1973	1965
Petroleum Jelly--All Grades	2911 X0 10	10,919	9,306	6,907	8,925	6,114	5,589
Petroleum Coke, except calcinated	2911 X0 25	172,858	158,841	150,416	78,943	63,205	42,027 1/
Microcrystalline Wax	2911 X0 80	14,419	14,749	9,239	16,026	11,341	8,726
Paraffin Wax--Crystalline, Fully Refined	2911 X0 33	15,263	9,886	12,689	10,520	7,180	21,347 2/
Paraffin Wax-Crystalline, except Fully Refined	2911 X0 37	7,442	6,362	5,574	7,918	5,655	N/A
Benzene	2911 X0 43	23,694	25,879	10,192	25,334	12,089	10,670
Toluene	2911 X0 47	79,950	76,293	46,955	44,010	28,842	7,230
Xylene, except Ortho- and Para-xylene	2911 X0 49	44,517	53,776	33,730	34,463	17,403	--
TOTAL:	2911	1,120,476	1,029,338	932,894	874,472	569,799	454,891

1/ Includes calcinated petroleum coke.

2/ Includes all crystalline paraffin wax.

NEC - not elsewhere classified.

Source: U. S. Department of Commerce, U. S. Exports, FT 610.

TABLE 11

PETROLEUM REFINERY PRODUCTS: VALUE OF IMPORTS
(thousands of dollars)

Description	Product Class	1977	1976	1975	1974	1973	1965
Gasoline	2911 10 00	371,814	133,124	313,591	574,687	140,991	27,689
Jet Fuel, Naphtha-Type	2911 20 20	40,515	337,674[1]	483,098	676,870	297,816	90,480
Jet Fuel, Kerosene-Type	2911 20 40	308,672	N/A	N/A	N/A	N/A	N/A
Kerosene Derived from Petroleum, Shale oil, or both (except motor fuel)	2911 30 00	13,324	2	511	20,418	6,946	3,990
Fuel Oil and Top Crudes Not Further Refined, Saybolt Universal Viscosity under 145 seconds	2911 40 01	741,837	306,423	497,792	1,003,366	715,814	13,904
Fuel Oil and Top Crudes Not Further Refined, Saybolt Universal Viscosity under 145 seconds	2911 50 01	5,187,536	4,363,541	3,966,199	5,062,764	1,687,143	698,072
Propane	2911 6E 45	N/A	218,859	191,566	157,071	79,838	N/A
Butadiene	2911 6E 50	115,930,256	82,398	67,163	99,603	26,541	N/A
Butylene, Ethylene, and Propylene	2911 6E 60	21,515	12,368	19,282	31,483	7,257	2,192[2]
Ethane, Propane, & Liquefied Petroleum Gases, NES; Derivatives of Petroleum or Natural Gas, NES	2911 6E 95	738,716	222,477[3]	181,203	218,288	79,581	8,462
Lubricating Oils Derived from Petroleum, Shale, or both	2911 70 20	32,336	4,987	3,778	6,652	1,101	1,009
Lubricating Greases Derived from Petroleum, Shale, or both	2911 70 40	592	515	381	484	426	110
Asphaltum, Bitumen, and Limestone-Rock Asphalt	2911 90 00	61,478	46,220	52,274	64,144	20,868	14,710

TABLE 11 (continued)

PETROLEUM REFINERY PRODUCTS: VALUE OF IMPORTS
(thousands of dollars)

Description	Product Class	1977	1976	1975	1974	1973	1965
Paraffin and Other Petroleum Waxes	2911 XD 35	8,519	5,318	6,128	11,356	8,899	265
Benzene	2911 XD 43	44,063	38,335	50,900	111,699	14,695	6,370
Toluene	2911 XD 47	33,250	20,050	9,824	30,264	20,529	1,962
Xylene	2911 XD 60	22,736	25,429	31,145	50,618	20,742	3,782
Naphthenic Acids	2911 XD 65	1,704	812	682	615	733	803
Naphthas, Derived from Petroleum, Shale Oil, etc., except Motor Fuel, Not to be further refined	2911 XD 75	952,543	47,625	50,613	199,076	46,583	11,530
Hydrocarbons, NES, and Hydrocarbon Mixtures, NES	2911 XD 95	81,494	146,900	135,354	98,938	27,979	N/A
Naphthas, Fuel Oil, and other Liquid Derivatives of Petroleum to be further refined.	2911 80 00	N/A	903,793	916,220	1,209,752	350,216	70,321
TOTAL:		8,823,584	6,916,853	6,978	9,628,151	3,554,698	955,652

1/Prior to 1977, jet fuel figures were not separated by type.

2/Includes sales of butadiene.

3/Figures prior to 1976 exclude ethane and propane.

NES - not elsewhere specified.

Source: U.S. Department of Commerce, U.S. Imports, FT 210.

Cyclic Crudes

CYCLIC CRUDES

DESCRIPTION

Cyclic crudes are organic chemicals which are isolated from coal tar by distillation. The raw material originates almost exclusively in the steel industry as a byproduct of coke manufacture. Although the components of coal tar vary greatly, depending upon the temperature, timing, and design of the coke oven, the most important cyclic crudes are fundamental aromatic compounds such as benzene, toluene, and the xylenes. They are used primarily as building blocks for more complex cyclic intermediates and end products. However, many crudes have end uses by themselves as solvents, fuels, wood and leather treatments, biocides, anti-oxidants, and roofing materials.

Essentially all cyclic crudes, except the multi-component residual fractions (creosote oil and tar pitch) have identical counterparts that are produced in petroleum refineries (SIC Code 2911). Indeed, coal tars currently account for only a small fraction of aromatic production (Table 1). However, coal served as the basis of the synthetic organic chemical industry until the discovery of the vast Middle East oil fields after World War II. Because of its low cost, availability, and ease of transport, petroleum quickly replaced coal tar as the primary chemical feedstock, and in the 1950s it facilitated rapid expansion of the chemical industry.

As Mideast tensions and the depletion of world oil reserves erode the price and quantity advantages of petroleum, an eventual return to coal-based feedstocks (including synfuels and synthesis gas) is expected.[1] However, in light of the intricate oil-based network which has developed over the last 30 years, the conversion will be very slow. The International Trade Commission notes that, "in some cases, (chemical) facilities are so sensitive that even a change in sources of petroleum feedstocks can cause an increase in operating cost. Obviously then, essentially entirely new facilities would be needed to process entirely new feedstocks."2/ It has been estimated that, in the absence of an appropriate industrial infrastructure, a coal-chemical plant would cost 60 to 100 percent more than a corresponding plant based on oil and natural gas. Consequently, petroleum and gas will remain the preferred feedstocks for at least the next decade.

1/The slow shift from oil to coal is already beginning. On January 9, 1980 Eastman Kodak announced plans to construct a plant that produces acetic anhydride from coal. The importance of this development is noted in the February 1, 1980 issue of Science.

2/U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1979).

TABLE 1

COMPETITION BETWEEN PETROLEUM AND COAL TAR IN THE PRODUCTION OF ELEMENTARY AROMATICS

BENZENE

Year	Percent of Total Volume That Was Produced from Coal-Tar	Price Per Gallon of Coal-Derived Product	Price Per Gallon of Oil-Derived Product	Coal/Oil Derived Price Ratio
1950	94.6	$.27	$.36	.75
1955	68.1	.35	.43	.81
1960	32.4	.32	.31	1 03
1965	14.6	.23	.24	.96
1970	8.2	.21	.22	.95
1975	9.3	.75	.70	1.07
1977	4.5	.82	.76	1.08

XYLENES

Year	Percent of Total Volume That Was Produced from Coal-Tar	Price Per Gallon of Coal-Derived Product	Price Per Gallon of Oil-Derived Product	Coal/Oil Derived Price Ratio
1950	13.1	$.27	$.23	1.5
1955	10.9	.33	.26	1.2
1960	2.8	.26	.21	1.2
1965	1.8	.22	.18	1.2
1970	0.8	.20	.17	1.1
1975	0 3	.55	45	1.2
1977	0.2	.63	.51	1.2

Source: Computed from figures in U.S. International Trade Commission, *Synthetic Organic Chemicals* (Washington, D.C.: Government Printing Office, various years).

INNOVATION

It is believe that the switch from petroleum to coal-based feedstocks will result in significant process innovation as old processes are restudied and entirely new ones are developed. However, all of the new research will be directed toward producing the same building blocks which have always been the staple of the chemical industry--the elementary alkanes, olefins, and aromatics. As a result, conversion will not by itself lead to the introduction of new chemicals.[3]

QUANTITY AND VALUE OF TRADE

Since virtually all coal tar is obtained as a byproduct of metallurgical coke ovens, the supply of cyclic crudes might be expected to follow the generally increasing demand for steel. However, this effect has been countered by the decrease in coke consumption per ton of steel which has resulted from the use of alternate fuels in blast furnaces. Consequently, production of tar and tar crudes has declined steadily since 1950 (Table 2).

A general price index for these products is not currently available, partially because the information is often obscured by petrochemical data. However, Table 1 indicates that the prices of individual cyclic crudes have moved in tandem with those of their petroleum-derived counterparts since 1960. This relation has been maintained even through the rapid increases in oil prices during the 1970s. Since coal prices did not keep pace with oil prices in this period,[4] prices of coal tar crudes are evidently not based on cost, but are determined by the petrochemical-dominated markets.

Since the 1973 oil embargo, the value of cyclic crude shipments has jumped dramatically, reflecting the increased prices (Table 3). For the 20 years before 1973, though, the value of shipments fluctuated near $90 million--even in the face of a steady decline in both quantities and production. This apparent contradiction can be explained at least in part by the influence of residual fractions, such as tar pitch, whose prices are not kept down by direct competition from petroleum products (Fig. 4).[5] The unusual behavior might also result from an increasing proportion of interplant transfers before 1973. Unfortunately, this hypothesis cannot be tested with publicly accessible information.

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[3] Of course, the conversion will be accompanied by the development of new catalytic preparations. These products, however, are discussed in a separate profile.

[4] ICF Inc., Discussion of Relationship of Coal and Oil Prices, Final Report to U.S. Department of Energy, February 1980.

[5] The increase in the prices of creosote oil and tar pitch since 1973 is probably due to the rising prices of both coal and petroleum-derived goods which are competitive with, but not identical to, the cyclic crudes.

TABLE 2

QUANTITIES OF PRODUCTION, SALES, AND CONSUMPTION OF COAL TAR
(millions of gallons)

Year	Production	Sales	Distillation	Fuel
1950	988	565	622	205
1955	914	--	679	142
1960	709	--	616	85
1965	802	--	616	122
1970	760	371	657	108
1975	645	285	450	162
1977	592	292	--	--

Source: U.S. International Trade Commission, *Synthetic Organic Chemicals* (Washington, D.C.: Government Printing Office, various years).

TABLE 3

VALUE OF SHIPMENTS
(million of dollars)

Year	Value
1954	87.4
1958	105.3
1963	79.3
1967	87.6
1972	80.9
1977	250.9

Source: U.S. Department of Commerce, Bureau of Census, *1977 Census of Manufactures* (Washington, D.C.: Government Printing Office, 1979 various years).

TABLE 4

PRICES OF TAR CRUDES WITH ONLY INDIRECT COMPETITION FROM PETROLEUM PRODUCTS

Year	Creosote Oil	Tar Pitch (Hard)
1950	$.16/gallon	$25.17/ton
1955	.20	33.30
1960	.22	39.07
1965	.21	38.11
1970	16	38.19
1975	.50	104.11
1977	.58	131.07

Source: U.S. International Trade Commission, *Synthetic Organic Chemicals* (Washington, D.C.: Government Printing Office, various years).

There are no statistics available to translate these shipment figures into value added. However, for establishments concentrating in tar crudes during 1972, value added amounted to $26.7 million, compared to $69.3 million in value of shipments.[6]

INDUSTRY STRUCTURE

The structure of the cyclic crudes industry has changed little since the 1950s. Only 12 firms have sales in excess of $100,000,[7] and of these, the top four control 92 percent of the "market".[8] While these figures suggest a high degree of concentration, the most important competition comes from the petrochemical industry. As previously mentioned, coal tar distillers are essentially price-takers, as are firms in a competitive market.

FOREIGN TRADE

Because trade statistics for chemicals are not collected by source, import and export data for cyclic crudes are almost invariably obscured by information on petrochemicals. When all data are considered, they show that most elementary aromatics have had more than a nominal trade surplus since 1973.[9] However, imports of benzene exceed imports due to inexpensive overseas sources, and the favorable trade balance is increasingly threatened by the prospect of a large-scale manufacture of aromatics in the Middle East. Prevention of further deterioration of the U.S. position, along with expansion of its trade surplus, may be brought about by technological advancements in obtaining chemicals from coal.

EMPLOYMENT

Complete employment figures are not available for the cyclic crude industry. However. 800 people were employed in the 21 establishments which concentrated in tar crudes in 1972.[10]

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[6] U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

[7] U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

[8] U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

[9] U.S. International Trade Commission, Synthetic Organic Chemicals, 1976 (Washington, D.C.: Government Printing Office, 1976).

[10] U.S. International Trade Commission, Industrial Organic Chemicals (Washington, D.C.: Government Printing Office, 1973).

Gum and Wood Chemicals

GUM AND WOOD CHEMICALS

DESCRIPTION

Gum and wood chemicals are made by either the carbonization of wood or the distillation of resin. They are often referred as to "naval stores", since for thousands of years they have been used for caulking on ships. They can be obtained from living and dead trees, but their major source is from the byproducts of kraft paper production (the production of wood pulp using a sodium sulfate solution).

USES

The major types of gum and wood chemicals are the following:

1) Rosin: Used in chemical intermediates and rubber (39 percent) paper sizing (32 percent), ester gums and synthetic resins (22 percent), surface coatings (2 percent), and other uses (5 percent);

2) Tall oil: obtained from kraft paper production, tall oil is a source of pitch (37 percent), rosin (25 percent), and fatty acids (22 percent);

3) Charcoal: used mostly for outdoor barbecuing; and

4) Turpentine: used as a paint thinner, and as a source of pine oil, insecticides, flavors and fragrances, and other products.

RAW MATERIALS

Gum and wood chemicals are obtained from living trees and from dead trees, stumps, and old logs. Gums are made by wounding living trees and obtaining the resin, and steam-distilled wood chemicals are made from dead trees, stumps, and old logs. Producers of these substances are currently facing shortages of both the raw materials and the unskilled labor needed for production. Therefore, wood chemicals are increasingly being obtained as byproducts of kraft paper manufacture. But kraft paper itself is becoming a less plentiful source of wood chemicals due to changes in paper-making technology and also due to an increase in the proportion of hardwood used in paper mills. These changes act to reduce the amounts of turpentine and tall oil being produced.

PUBLIC DATA

As can be seen in Table 1, the gum and wood chemicals industry is either stagnant or declining. The value of shipments, value added by manufacturers, and fixed assets have not increased in real terms for the last two decades, and the number of employees and establishments have both decreased. This

TABLE 1

GUM AND WOOD CHEMICALS: INDUSTRY DATA

Year	Number of Establishments	Employees (thousands)	Value Added by Manufacturer (million $)	Value of Shipments (million $)	Gross Value of Fixed Assets (million $)
1977	121	5.0	202.2	440.3	227.1
1976		4.7	147.2	364.8	184.6
1975		4.6	130.2	314.2	162.1
1974		5.1	199.5	403.3	148.8
1973		5.5	181.1	355.4	210.6
1972	139	5.9	155.4	332.3	203.1
1971		5.2	139.8	279.4	167.9
1970		5.3	116.3	261.7	165.3
1969		5.8	102.3	228.5	152.8
1968		5.7	117.2	233.3	147.8
1967	184	5.9	100.8	215.9	139.2
1966		5.0	99.2	208.7	
1965		5.8	92.6	206.2	
1964		6.4	102.3	222.0	118.1
1963	246	6.8	100.3	212.9	115.2
1962		6.2	100.5	199.6	111.2
1961		6.7	99.1	201.0	

Source: U.S. Department of Commerce, Bureau of the Census, Census of Manufactures and Annual Survey of Manufactures (Washington, D.C.: Government Printing Office, various years).

TABLE 2

PRICE INDICES OF SELECTED GUM AND WOOD CHEMICALS

(1967 = 100)

Year	Rosin[a]	Turpentine[a]	Tall Oil[b]
1976	239.9	247.4	186.2
1975	242.8	276.1	216.7
1974	346.7	242 0	297.4
1973	219.3	140.3	166.0
1972	182.3	182.2	131.8
1971	163.4	209.1	138.0
1970	145.1	209.1	121.4
1969	113.9	198.3	111.5
1968	100.9	134.1	125.3
1967	100.0	100.0	100.0

[a] Based on crop year, running from April 1 to March 31.
[b] Based on calendar year.

Sources: Data on rosin and turpentine: Mary K. Meegan, ed., *Kline Guide to the Chemical Industry* (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 69.

Data on tall oil: U.S. Department of Commerce, *U.S. Exports*: *Commodity by Country*, FT 410 (Washington, D.C.: Government Printing Office, various years).

stagnation is partly due to problems of supply, as discussed above. That the stagnation is due primarily to supply problems is reflected in the prices of gum and wood chemicals (see Table 2). Such prices rose steadily even before the inflation of the 1970s, and during the 1970s they outpaced the general level of inflation. This behavior is indicative of products whose supply is constricted.

Imports of gum and wood chemicals are negligible, but exports are substantial; the U.S. is a major world supplier of these products. Table 3 displays total U.S. exports and exports as a percentage of shipments. Throughout the period 1967 to 1976 exports accounted for about 20 percent of total U.S. production.

TABLE 3

EXPORTS OF GUM AND WOOD CHEMICALS

Year	Total (million $)	Percentage of Value of Shipments
1976	81	22.2
1975	53	16.9
1974	88	21.8
1973	72	20.3
1972	58	17.5
1971	58	20.8
1970	62	23.7
1969	47	20 6
1968	49	21.0
1967	46	21.3

Source: U.S. Department of Commerce, U.S. Exports: Commodity by Country, FT 410, various years.

The degree of concentration in the manufacture of gum and wood chemicals is shown in Table 4. Concentration is moderate to high, and appears to have increased somewhat in recent years. Presenting only the concentration ratio for the entire industry conceals major differences in the different sectors of the industry. As shown in Table 5, the production of soft wood distillation products is highly concentrated. However, the production of other gum and wood chemicals including gums, charcoal, and tall oil is much less concentrated, though concentration has increased in recent years.

COMPANIES IN SEGMENT

Crude tall oil is produced by almost all kraft paper producers, but there are only eight (according to the Kline Guide) or nine (according to the Census of Manufactures) firms which process tall oil. The eight firms listed by the Census of Manufactures are Hercules, Crosby Chemical, Arizona Chemical, Union Camp, Sylvachem, Reichhold Chemicals, Westvaco, and Monsanto. Major producers of steam-distilled rosin and turpentine are Hercules, Reichhold, and Continen-

TABLE 4

CONCENTRATION RATIOS FOR PRODUCT CLASS 2861: GUM AND WOOD CHEMICALS
(in percent)

Year	Four Firm Ratio	Eight Firm Ratio	Twenty Firm Ratio	Fifty Firm Ratio
1972	49	64	78	92
1967	51	63	76	89
1963	44	54	69	86

Source: U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

TABLE 5

CONCENTRATION RATIOS FOR PRODUCT CLASSES 28611 AND 28612
(in percent)

	Year	Four Firm Ratio	Eight Firm Ratio	Twenty Firm Ratio	Fifty Firm Ratio
28611, Softwood distillation products	1972	90	97	100	--
	1967	85	93	100	--
	1963	N/A	91	99	100
	1958	80	92	98	99
	1954	83	94	99	N/A
28612, Other gum and wood chemicals	1972	36	54	76	95
	1967	36	50	69	70
	1963	25	38	60	85
	1958	27	41	67	88

Source: U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures, (Washington, D.C.: Government Printing Office, 1975).

tal Turpentine and Rosin. Kingsford, Georgia-Pacific, Great Lakes Carbon, and Husky Industries are important producers of charcoal, and Shelton Naval Stores, Monsanto, Stallworth Pine Products, Taylor-Lowenstein, Union Camp, Varn Gum Turpentine and Vidalia Gum Turpentine are producers of gum products. All of these firms are either closely held firms, whose financial records are not available, or subsidiaries or units of very large conglomerates. Therefore, the information necessary to determine the profitability of the gum and wood chemicals industry is not available.

INNOVATION

While there does seem to be some development of new gum or wood chemicals, if innovation in the industry is measured by the amount which is mentioned in the trade journals, there is little innovation in this sector. However, the huge petroleum price increases of the last ten years have apparently brought a renewed interest in biomass-based chemicals. Given the large oil-based chemical industry which now exists, however, any expansion of the use of gum and wood chemicals will be slow.

Organic Chemicals, NEC

Organic Chemicals, NEC Segment Summary

Cyclic Intermediates

Miscellaneous Organic Chemicals

Synthetic Organic Dyes and Pigments

Plasticizers

Rubber-Processing Chemicals

The Organic Chemical, NEC segment consists of organic chemicals that do not fit into the other organic chemical categories because of their unique structures and functions. As a whole, this segment is highly innovative, although some of its components (synthetic organic dyes and pigments, and miscellaneous acyclic chemicals) are not. Cyclic intermediates are distinguished from other chemicals by both structure and function. Cyclic intermediates all consist of various functional groups which are attached to (or built into) a carbon framework that contains at least one ring. Cyclic intermediates are typically used in the production of end use products, although they also have end uses as biocides, photographic chemicals, fuel additives, and antioxidants.

There are a few cyclic intermediates which have always dominated the industry. A group of eleven (cumene, cyclohexane, ethylbenzene, styrene, o-xylene, p-xylene, alkyl benzene, arilene, chlorobenzene, phenol, and phthalic anhdride) has traditionally accounted for 65-70 percent of production volume and 40-50 percent of sales volume. But despite the dominance of these large-volume commodity chemicals, innovation in this component is quite high. In general, there are many paths by which end-use chemicals can be produced from the initial feedstock. Each process innovation in which a new path from feedstock to end use product is discovered may result in the production of several new chemical intermediates for use in the new process. In addition, new intermediates may result from the search for new end-use products, and may also be produced along with new end-use products.

The structure of the cyclic intermediate industry as a whole is difficult to describe. The large-volume commodity chemicals typically have more than ten major producers. However, many of the intermediates are produced by only one firm. Since there are many ways to produce most cyclic compounds, there is some competition among the different intermediates. In discussing the structure of the cyclic intermediate industry, one should also note that oil companies command a significant share of the market, particularly in the production of large volume commodity chemicals. They have been attracted to the industry by the close relationship between many cyclics and refinery products.

Miscellaneous cyclic chemicals include end-use cyclic compounds such as gas and oil additives, many oil field chemicals, photographic chemicals, tanning materials, paint driers, enzymes, and some flavorings. In general, there is a high rate of innovation among end-use cyclics, just as among intermediate cyclics. It is difficult to say much more about the innovativeness and structure of the industries producing miscellaneous end-use cyclics, since data on these chemicals is often grouped with miscellaneous acyclic chemicals - a much larger, though less innovative group.

Plasticizers are organic chemicals which are physically incorporated into plastics, either to improve workability during fabrication or to increase flexibility in the end-use products. About 85 percent of all plasticizers are used in the plastics industry (about two thirds of the total in polyvinyl chloride), with the rest being used in the production of rubber and cellulosic products.

There is a great deal of innovation in the plasticizer industry, particularly involving the relatively new polymeric plasticizers. Even though the roster of basic plastics has been relatively unchanged for twenty years, during that time, thousands of new end-use products have been developed for these basic plastics. Often, a new product will be associated with a new type of plasticizer.

In the mid 1970s the leading four firms produced just over 50 percent of all plasticizers, and the leading eight firms just over 70 percent. In more narrowly defined markets (e.g., phthalates, phosphate esters, and polymeric plasticizers) the concentration ratios are somewhat higher. There has been some turnover among the leading plasticizer producers in the last twenty years. Allied Chemicals and Celanese, both among the leading plasticizer producers in the 1960s, no longer produce phthalate plasticizers. U.S. Steel, Exxon, Stauffer, Tenneco, and BASF Wyandotte have become major plasticizer producers, either by buying small producers and expanding or by beginning production from scratch.

Rubber-processed chemicals include a wide variety of substances that modify rubber so it can be used in commercial applications. Not all of the chemicals which are used in rubber production are included in this category; such products as sulfuric acid, salt, alum, sulfur, zinc oxide, fatty acids, silicas, clays, carbon black, nylon, rayon and pigments have many uses outside the rubber industry, and are not included in this segment. The major categories of rubber-processing chemicals (out of a total of several dozen categories) are:

1) Accelerators -- cause rubber to vulcanize faster; in addition, they often retard aging;

2) Activators -- increase the efficiency of vulcanization;

3) Antioxidants -- protect rubber from deterioration due to the action of oxygen and oxidizing chemicals; and

4) Antiozonants -- protect rubber from deterioration due to the action of ozone.

As with plastics, there has not been much innovation in the roster of basic synthetic rubbers during the last twenty years, but hundreds of new end-use products have been developed from those basic rubbers. One or more new rubber-processing chemicals are associated with many of these products. Not only have new rubber-processing chemicals of a given type been introduced, but entire new types have been created.

The major tire companies are important producers of rubber-processing chemicals. Goodrich, Goodyear, and Uniroyal produce about half of the total. Much of the volume produced by major rubber producers is used in their own rubber factories. It should be noted that the advantage that a high degree of concentration would normally give the rubber-processing chemicals industry is somewhat negated by the high degree of concentration among rubber producers, the buyers of rubber-processing chemicals.

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Cyclic Intermediates

CYCLIC INTERMEDIATES

DESCRIPTION

Cyclic intermediates are organic chemicals which are grouped together because of a common chemical "architecture". They all consist of various functional groups that are attached to (or built into) a carbon framework containing at least one ring. Although the vast majority are used as intermediates in the production of higher cyclics, they also have end uses as biocides, photographic chemicals, fuel additives, and antioxidants. Indeed, many individual cyclic intermediates are used in more than one of these areas.

The similarity in the structure of cyclic intermediates causes similaritity in their production. The carbon skeleton of these compounds can be formed either by dismembering a more complex ring frame or, more commonly, by linking smaller molecules together. Although the cyclic portion(s) can be formed from acyclic recursors, it is almost always easier to use prefabricated structural units like the phenyl or benzene ring. For this reason, the majority of cyclic intermediates are derived from simpler cyclic compounds which are produced either inside the industry or in the petrochemical or cyclic crudes industries.

The functional properties of the molecules can be adjusted at various points in the reaction sequence by the introduction, deletion, or exchange of attached groups. These alterations typically involve organic compounds (both cyclic and acyclic) and industrial inorganic chemicals. Occasionally, the reactions require catalysts.

Because of the way in which cyclic intermediates are constructed, there are many different routes to all but the most complicated synthetic goals. For example, phenol, a widely used organic intermediate, is currently produced through six distinct commerical processes.1/ Although new synthetic techniques are always being discovered, many of the fundamental organic reactions have been known for 100 years. Consequently, the method of producing cyclic intermediates is usually determined by economic rather than scientific factors.

1/B.G. Reuben and M.L. Burstall, The Chemical Economy (London: Longman Group, Ltd., 1973).

INNOVATION

It seems possible to isolate a large portion of the cyclic intermediate industry for which virtually no product innovation takes place. Because of the way in which cyclic intermediates are synthesized, there are a few elementary building block cyclics which have always dominated the industry. A group of only six has traditionally accounted for 50-60 percent of the production volume and 30 to 35 percent of the sales value (Table 1). For the top 11 of these fundamental cyclics, the proportions increase to 65 to 70 percent and 40 to 50 percent, respectively. When other compounds that are reported only sporadically by the International Trade Commission (ITC) are included, it becomes clear that more than half of the sales value is derived from a non-innovative portion of the industry. Yet, despite the dominance of the large-volume commodity chemicals, innovation appears to be quite high in the segment. In general, there are many paths by which end-use chemicals can be produced from the initial feedstocks. Each process innovation in which a new path from feedstock to end use product is discovered may result in the roduction of several new chemical intermediates for use in the new process. In addition, new intermediates may result from the search for new end-use products.

QUANTITY AND VALUE OF TRADE

The quantity of cyclic intermediates produced and sold has increased steadily since the 1950s as a result of rising demand for the end products--from both inside and outside the chemical industry--which are derived from these compounds (Table 2). The segment is very competitive because, in many product lines, high growth and profit potential coexist.[2]

Pricing trends have not been consistent (Tables 2 and 3). Before 1973 prices declined due to both economies of scale and competition. Since 1973, however, increases in the price of petroleum raw materials has caused a dramatic price rise.

Despite falling prices during the 1950s and 1960s, quantities increased enough in this period to permit constant expansion in the value of shipments (Table 4). The more recent combination of rising quantities and prices has accelerated this growth.

Unfortunately, the shipment figures greatly overstate the impact of cyclic crudes on the economy. As the ITC points out, "since many of the intermediates included in the statistics represent successive steps in production, the totals necessarily include considerable duplication."[3]

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[2] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

[3] U.S. International Trade Commission, Synthetic Organic Chemicals, 1965 (Washington, D.C.: Government Printing Office, 1965).

TABLE 1

PRODUCTION AND SALES FOR 11 BASIC CYCLIC CHEMICALS

	Quantity of Production (1000 lbs				Quantity of Sales (1000 lbs				Value of Sales ($1000)				Uses
	65	70	75	77	65	70	75	77	65	70	75	77	
Cumene	663	1983	2003	2644	-	1200	1100	1294	-	46	124	160	95% intermediate (phenol, acetone, etc.
Cyclohexane	1700	1841	1734	3020	1475	1976	1722	2198	60	62	211	261	90% intermediate (adipic acid, caprolactam, etc.
Ethylbenzene	3023	4827	4822	8312	580	513	490	211	24	19	43	29	95% intermediate (styrene)
Styrene	2864	4335	4673	6867	1248	2013	1964	2799	95	130	368	520	95% monomeric "intermediate"
O-xylene	351	799	702	985	344	777	697	810	9	23	58	271	70% intermediate (phthalic anhydride); 30% fuel and solvent
p-Xylene	396	1590	2484	3172	375	1294	1879	1841	33	82	267	170	90% intermediate (TPA and DMT)
Subtotal	8997	15375	16418	25000	(4022)	7593	7862	9152	(221)	362	1071	1411	
Percent	53.3	54.4	52.3	57.2	(53.3)	58.5	53.2	53.4	(27.1)	28.7	33.8	35.2	
Alkyl benzene	645	553	495	526	583	536	428	456	56	54	109	117	Intermediate (detergents)
Ariline	196	398	407	584	76	195	151	176	10	22	34	42	95% intermediate (isolyanates, etc.)
Chlorobeneze	546	485	306	325	82	67	77	175	5	7	20	35	70% intermediate; 20% solvent
Phenol	1229	1755	1746	2338	533	769	927	1206	50	54	237	232	90% intermediate (phenolic resins, bisphenol A, etc
Phthalic anhydride	608	734	702	926	336	441	436	567	28	40	92	128	95% intermediate (plasticizers and resins)
Subtotal	3224	3925	3656	4699	1610	2008	2019	2580	149	177	492	554	
Total	12221	19300	20074	29699	(5632)	9601	9881	11732	(370)	539	1563	1965	
Percent	72.5	68.3	63.9	67.9	(74.6)	74.0	66.9	68.5	(45.5)	42.8	49.3	49.0	

Sources: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years); and Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed. Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977).

TABLE 2

PRODUCTION AND SALES OF CYCLIC INTERMEDIATES

Year	Production Quantity (million lbs.)	Sales Quantity (million lbs.)	Sales Value (million $)	Unit Value
1955	6,016	2,284	407	1.18
1960	9,612	3,964	662	.16
1965	16,865	7,551	814	.10
1970	28,257	12,976	1,260	.10
1975	31,413	14,780	3,169	.21
1977	43,726	17,138	4,008	.23

Source: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

TABLE 3

WHOLESALE PRICE INDEX FOR BASIC AND INTERMEDIATE CYCLICS

(Group definitions do not correspond exactly with Census definitions.)

Year	Basic Cyclics	Cyclic Intermediates
1968	80.8	79.7
1970	79.2	74.0
1972	102.7	89.0
1974	109.3	102.2
1976	243.4	234.7
1978	271.0	241.1

Note: The base year for the Wholesale Price Index figures changes in 1974 from 1958 to 1973. Adjusting for this difference would have an effect of only one or two points, and would have no influence on the qualitative interpretation.

Source: U.S. Department of Commerce, Wholesale Price Index, 1979.

TABLE 4

VALUE OF SHIPMENTS

Year	Value of Shipment (millions of dollars)
1954	$ 466
1958	531
1963	758
1967	1,066
1972	1,538
1977	4,001

Sources: U.S. Department of Labor, Bureau of the Census, 1972 Census of Manufactures and 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975 and 1979).

For example, 63 percent of all cumene roduced is used to synthesize phenol. Fourteen percent of the phenol (which also comes from other sources) is then used to manufacture bisphenol A, a precursor of numerous resins.[4] Since all three compounds are among the highest volume cyclic intermediates, the magnitude of multiple reporting is quite significant. Consequently, the value added by the segment is a better indicator of its importance, but complete data is not available. However, for the 49 establishments which concentrate in cyclic intermediates, values added amounted to $504.4 million, or 43 percent of the value of shipments, in 1972.[5]

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[4] Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed., Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977).

[5] U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

INDUSTRY STRUCTURE

The cyclic intermediates industry has been characterized by high and increasing competition. In 1977, 85 companies had industry shipments of over $100,000.[6] The top eight firms held a market share of 62 percent, compared to 81 percent in 1954 (Table 5). More recently, there have been indications of a reversal in this trend. The five largest producers of benzenoid chemicals (which include a substantial amount of acyclic compounds that can be manufactured from cyclic precursors) increased their market share from 25 percent in 1973 to 37 percent in 1977.[7]

Of course, these figures are not sufficient evidence on which to base conclusions about the extent of competition in the industry. The reason is that the market structure varies widely depending upon the chemical in question. The fundamental, high-volume compounds like phenol, phthalic anhydride, and styrene typically have more than ten major producers. However, the ITC lists only one producer for 65 percent of the 950 cyclic intermediates that it examines.[8] The extent of competition between the smaller-volume chemicals is not clear. Since there are many ways to produce most cyclic compounds, there is probably significant competition between the substances in their use as synthetic intermediates. The same does not necessarily hold for their end uses, however.

TABLE 5

CONCENTRATION RATIOS

Year	Percent of Value of Shipments Accounted for by X Largest Firms			
	X = 4	8	20	50
1954	55	81	94	--
1958	52	72	90	99
1963	53	58	87	98
1967	47	63	83	97
1972	43	62	84	97

Source: U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

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[6] Ibid.

[7] U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977).

[8] Ibid. However, previous ICF studies on pesticides indicate that ITC information on producers may not be complete.

Besides the factor of competition, another important influence on the operation of the industry is its relation to the petroleum industry. Oil companies command a significant market share--particularly in the production of elementary, high volume cyclics--despite the fact that chemical products as a whole account for only 3 to 28 percent of the sales of major petroleum producers (Table 6). They have been attracted into the industry by the potential for high profits and the close relation of many cyclics to refinery products. Conversely, many of the large chemical companies have diversified backwards into the oil industry to protect and supplement their supplies of raw materials.[9]

EMPLOYMENT

Exact employment figures for the cyclic intermediate industry are not available, but can be approximated by using a variety of census data. Together with manufacture of cyclic crudes and organic dyes, production of cyclic intermediates employed 33,000 people in 1977.[10] One way to estimate what proportion of this labor force actually worked in the cyclic intermediate industry is by noting that this sector accounted for 74 percent of the combined values of shipments.[11] However, one cannot assume a priori that the three industries are equally labor intensive. Table 7 shows the 1972 values of shipments and employment figures for establishments concentrating in each of the sectors. Using these figures as a proxy for labor productivity, employment in the cyclic intermediate industry can be estimated at 19,200.[12]

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[9] Meegan, Kline Guide.

[10] U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

[11] Ibid.

[12] The estimate was made by assuming a constant ratio of productivities, where productivity is defined as the value of shipments per employee. Mathematically,

$$(V_1^{72}/E_1^{72}) \,/\, (V_2^{72}/E_2^{72}) =$$

$$(V_1^{77}/E_1^{77}) \,/\, (V_2^{77}/E_2^{77})$$

where V_1, is the value of shipments in cyclic intermediates, E_1 is the employment in cyclic intermediates, V_2 and E_2 are the corresponding figures for the aggregate of other industries, and the superscripts indicate the year. The 1972 statistics are only for respective areas, while 1977 data are for the entire industry.

TABLE 6

THE ROLE OF OIL COMPANIES AMONG THE TOP 20 CHEMICAL PRODUCERS

(Separate data for cyclic intermediates are not available.)

Rank by World Chemical Sales	Company	World Chemical Sales ($ million)	Total Sales ($ million)	Percent Chemical Sales
1	DuPont	7,300	8,361	87.3
2	Dow Chemical	4,320	5,652	76.4
3	Union Carbide	4,000	6,346	63.0
4	Monsanto	3,577	4,270	83.8
5	Exxon[a]	3,238	48,631	6.7
6	Celanese	1,855	2,123	87.4
7	Allied Chemical	1,738	2,630	66.1
8	Shell Oil[a]	1,574	9,230	17.1
9	Occidential Petroleum[a]	1,536	5,534	27.8
10	Standard Oil (Ind.)[a]	1,432	11,532	12.4
11	WR Grace	1,385	3,615	38.3
12	Hercules	1,375	1,596	86.2
13	Eastman Kodak	1,247	5,438	23.0
14	Phillips Petroleum[a]	1,230	5,698	21.6
15	American Cyanamid	1,096	2,094	52.3
16	Gulf Oil[a]	1,062	16,451	6.5
17	Texaco[a]	1,000	26,452	3.8
18	Stauffer	910	1,100	82.7
19	PPG Industries	904	2,255	40.1
20	Atlantic Richfield[a]	826	8,462	9.8

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[a] Oil companies.

Source: Mary K. Meegan, ed., *Kline Guide to the Chemical Industry* (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 7

EMPLOYMENT AND SHIPMENT VALUES FOR ESTABLISHMENTS CONCENTRATING IN THREE INDUSTRIES

	Number Employees	Value (millions of dollars)
Cyclic Intermediates	11,300	$1,176.4
Dyes and Pigments	15,600	766.8
Cyclic Crudes	800	69.3

Source: U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

TABLE 8

FOREIGN TRADE OF CYCLIC INTERMEDIATES

	Imports			Exports		
	Quantity (million lbs.)	Value (million $)	Unit Value ($/lb.)	Quantity (million lbs.)	Value (million $)	Unit Value (/lb.)
1973	603	186	.31	2,971	356	.12
1974	827	332	.40	2,957	732	.25
1975	486	276	.57	2,693	564	.21
1976	645	354	.55	3,418	764	.22
1977	867	390	.45	3,340	740	.22

Sources: U.S. Department of Commerce, U.S. Imports, FT 210, various years, and U.S. Exports, FT 610, various years.

FOREIGN TRADE

The United States maintains a positive balance of trade in cyclic intermediates. Between 1973 and 1977 the value of exports exceeded that of imports by a factor of 1.9 to 2.2 (Table 8). A total of 819 benzenoid chemicals were imported in 1977, the most important ones being phthalic anhydride and cyclohexane. Imports from member nations of the Organization for Economic Cooperation and Development (OECD) accounted for 89 percent of the total value of imported cyclic intermediates. Exports, on the other hand, went principally to the Netherlands, Canada, Brazil, Mexico, and Belgium. The main items exported in 1977 were styrene, toluene diisocyanates, detergent alkylates, and cyclohexane.13/

Close inspection of the trade figures reveal further information about the nature of the other traded chemicals. Exports as a group have consistently exhibited a lower unit value than imports (Table 8). This relation holds true despite the fact that the values of individual chemicals, as assessed at the respective site of export, are typically lower overseas.14/ Apparently, the U.S. imports a significantly greater proportion of high-priced, specialty cyclics than it exports.

13/U.S. International Trade Commission, Synthetic Organic Chemicals, 1977.

14/Ibid.

Miscellaneous Organics

MISCELLANEOUS ORGANIC CHEMICALS

DESCRIPTION

The miscellaneous organic chemicals are all the synthetic products which are not classified elsewhere. Acyclic organics dominate the group, accounting for over 90 percent of production and sales value.1/ Like the cyclic intermediates, these chemicals consist of various reactive functional groups which are either attached onto or built into a carbon framework. However, instead of containing ringed structures, the skeleton of acyclics are strictly linear or branched. The compounds are frequently used as intermediates, but also find end uses such as gasoline additives, refrigerants, preservatives, oil-well chemicals, foods, antifreeze, and biocides.

Unfortunately, the acyclic chemicals cannot be treated independently due to inconsistencies in reporting practices by the International Trade Commission (ITC) and Bureau of the Census.2/ In addition to acyclics, the miscellaneous organic chemicals category includes "end use" cyclic compounds such as gas and oil additives, photographic chemicals, tanning materials, paint driers, enzymes, and some flavorings.

PROCESSES FOR PRODUCING ACYCLIC ORGANICS

Acyclic carbon frameworks are typically synthesized by joining small units together. Consequently, most of these compounds are derived from simpler acyclics roduced either inside or outside of the industry. As with cyclic organic chemicals, changing the functionalism requires some combination of organic and inorganic reagents, often in the presence of a catalyst. Since a molecule can be "pieced together" in many different ways--most of which are based on well known synthetic techniques--the choice of a production process depends primarily on economic considerations.

1/U.S. International Trade Commission, Synthetic Organic Chemicals, 1975 (Washington, D.C. Government Printing Office, 1975) and U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975)

2/The ITC and Bureau of the Census changed the methods of classification between 1975 and 1976 so that acrylic chemicals are no longer separate. Furthermore, the ITC does not have any category corresponding to SIC 28695. Finally, the Bureau of the Census removed urea from this group of industries in 1972 while the ITC did not.

INNOVATION

One can isolate a large portion of the industry in which there are essentially no new products being introduced. Because of the way in which acyclics are synthesized, there are a few "building block" compounds that have always dominated the industry. Table 1 shows that 24 of these have historically accounted for 55 to 60 percent of production volume and 25 to 35 percent of sales value. This portion of the industry will likely remain non-innovative. There is a good deal of innovation, however, in the end use portion of this segment, where the rate of introduction of new "specialty chemicals" has been high. Slight modifications are frequently made in the structure of these compounds in order to bring about marginal changes in their functional properties.

QUANTITY AND VALUE OF TRADE

Production of miscellaneous organic chemicals has increased steadily in response to rising demand for the end products that are derived from these chemicals (Table 2). This demand has been generated from other chemical industry segments and from outside the chemical industry. Due to both economies of scale and excessive competition, prices continued to decrease until the 1973 oil embargo forced a sharp reversal in the trend (Tables 2 and 3). Even when prices were declining, shipment values were increasing as a result of increased volumes (Table 4).

As in the case of cyclic intermediates, calculating value of shipments involves extensive duplication because many chemicals simply represent successive steps in a production process. Value added statistics would avoid this problem, but complete data is not currently available. Nevertheless, for establishments concentrating in miscellaneous organics in 1972, value added amounted to $4 338 million, or 55 percent of the value of shipments.[3]

INDUSTRY STRUCTURE

It is difficult to draw generalizations about such a diverse group of roducts and markets as miscellaneous organic chemicals . Although the concentration ratios in Table 5 indicate a moderate and increasing degree of competition, the actual degrees for specific chemicals range widely.

Synthesis of high-volume compounds is usually quite competitive, with as many as 13 producers involved in the same market.[4] (One notable exception is the $400 million fluorocarbon industry, which DuPont dominates with a 45 percent share.)[5] The leading manufacturers are often different from

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[3] U.S. International Trade Commission, Industrial Inorganic Chemials (Washington, D.C.: Government Printing Office, 1975).

[4] U.S. International Trade Commission, Synthetic Organic Chemicals, 1977.

[5] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977).

TABLE 1

PRODUCTION AND SALES FOR 24 BASIC ACYCLIC CHEMICALS: VARIOUS YEARS

Chemical	Quantity of Production (1000 lbs)				Quantity of Sales (1000 lbs)				Value of Sales ($1000)				Uses
	65	70	75	77	65	70	75	77	65	70	75	77	
Acrylonitrile	772	1039	1215	1646	303	547	524	526	48	60	122	128	80% monomer; intermediate; fumigant
Acetic Acid	1347	1932	2197	2570	294	389	599	600	20	23	65	80	90% intermediate (vinyl acetate, cellulose acetate, TPA, DMT, etc.)
Acetic Anhydrile	1532	1589	1458	(1500)	180	161	(150)	139	18	14	(25)	31	intermediate (vinyl acetate, resins, etc.
Adipic Acid	866	1082	1343	1536	70	127	107	181	16	20	39	62	90% monomer (nylon)
Maleic Anhydride	128	215	215	294	94	151	170	224	11	24	57	69	intermediate (resins, pesticides); preservative
Acetone	1124	1615	1640	2219	741	1124	1311	1556	34	45	156	211	50% intermediate (methyl methacrylate, etc.); 20% solvent
Methyl-Ethyl Ketone	318	480	425	511	301	427	432	509	32	39	77	95	Solvent; intermediate
Formaldehyde	3107	4427	4558	6046	1189	1381	1598	2790	30	33	61	128	50% monomer; 40% intermediate; biocide; corrsion inhibitor
n-Butanol	429	468	490	840	292	278	328	420	27	22	60	73	70% intermediate; dehydrating agent
Ethanol	2039	1957	1429	1339	1315	1060	1110	943	77	67	145	171	Solvent; intermediate; beverage; antiseptic
iso-Propanol	1538	1919	1521	1888	582	861	813	1282	36	49	92	162	intermediate; solvent; antiseptic; dehydrating agent; preservative
Methanol	2869	4932	5176	6453	1345	1861	2409	3630	44	53	136	210	90% intermediate (formaldehyde, DMT, etc.); 10% solvent
Ethylene Glycol	1798	3038	3809	3675	1198	2210	2848	2958	104	146	586	557	50% antifreeze; intermediate; solvent; brake fluid; coolant
Propylene Glycol	213	428	391	489	189	395	366	487	20	36	97	121	70% intermediate (resins, etc.); solvent; coolant; feed additive; preservative
Carbon Terrachloride	594	1011	906	809	509	841	484	385	37	44	65	49	90% intermediate (fluorocarbons); rodenticide; solvent; fire extinguisher
Ethyl Chloride	686	678	575	612	274	273	280	296	19	17	28	41	intermediate (tetraethyl lead, etc.); solvent; anesthetic
Chloroform	152	240	262	302	123	175	192	285	10	11	30	49	80% intermediate (fluorocarbons, drugs); solvent; insecticide
Ethylene dichloride	2456	1460	7977	10997	309	1314	726	1526	14	38	62	123	95% intermediate (vinyl chloride, perchloroethylene, trichloroethylene)
Methylene chloride	211	402	497	478	195	358	435	475	17	29	68	87	60% solvent; 20% propellant; intermediate
Pechloroethylene	429	707	679	614	385	640	589	527	32	45	83	63	80% solvent (especially for dry cleaning); 15% intermediate (fluorocarbons)
Trichloro-ethylene	435	611	293	297	428	569	290	295	36	40	44	47	95% solvent (especially for metal degreasing); intermediate; anesthetic
Vinyl chloride	2000	4040	4196	5986	688	2720	2245	4127	42	107	221	508	95% + monomer
Ethylene oxide	2190	3865	4467	4364	256	411	409	549	26	29	105	129	intermediate (ethylene and higher glycols, detergents); rocket propellant
Propylene oxide	604	1179	1524	1866	69	172	(200)	(200)	8	15	(30)	(30)	intermediate (glycols and detergents); fumigant
Total	27808	45185	47061	57229	11385	18439	18669	24945	754	1005	2454	3208	
Percent of Industry Total	57.6	61.9	59.9	59.5	58.2	60.4	57.0	59.8	27.0	25.5	32.6	32.5	

Sources: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years); Gloria M. Lawler, ed., Chemical Origins and Markets (5th ed., Menlo Park, CA: Chemical Information Services, Stanford Research Institute, 1977); and Gessner G. Hawley, ed., The Condensed Chemical Dictionary (8th ed., New York: Van Nostrand Reinhold Company, 1971).

TABLE 2

PRODUCTION AND SALES OF MISCELLANEOUS ORGANIC CHEMICALS

Year	Production Quantity (thousands of pounds)	Sales Quantity (thousands of pounds)	Sales Value (thousands of pounds)	Unit Value (dollars/ pounds)
1965	48,263	19,573	2,791	.143
1970	73,019	30,542	3,940	.129
1975	78,645	32,760	7,542	.230
1977	96,172	96,172	9,897	.237

Source: Computed from data in U.S. International Trade Commission, *Synthetic Organic Chemicals* (Washington, D.C.: Government Printing Office, various years).

TABLE 3

WHOLESALE PRICE INDEX FOR ORGANIC CHEMICALS OTHER THAN BASIC AND INTERMEDIATE CYCLICS

(The group definition does not correspond exactly with the Census definition).

Year	Price
1968	91.9
1970	89 0
1972	98.3
1974	102.1
1976	224 5
1978	228 7

Note: The base year for the Wholesale Price Index figures changes in 1974 from 1958 to 1973. Adjusting for this difference would have an effect of only one or two points, and would have no influence on the qualitative interpretation.

Source: U.S. Department of Commerce, *Wholesale Price Index,* various years.

TABLE 4

VALUES OF SHIPMENTS FOR MISCELLANEOUS ORGANIC CHEMICALS

(millions of dollars)

Year	Value of Shipments
1954	$ 1,655.2
1958	2.391.3
1963	3,546.7
1967	4,606 7
1972	6,180.5
1977	15,213.9

Sources: U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures and 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975 and 1979).

TABLE 5

CONCENTRATION RATIOS

1972 SIC Code	Year	Percent of value of shipments accounted for by X largest firms			
		X = 4	8	20	50
28691 (cyclics)	1972	33	48	75	96
	1967	31	45	70	94
	1963	29	34	71	94
	1958	39	60	85	99
	1954	44	66	88	--
28692 (acyclics)	1972	43	58	79	94
	1967	47	62	82	95
	1963	51	65	84	96
	1958	59	72	90	98
	1954	64	77	92	--
28695 (NEC)	1072	28	43	69	92
	1967	30	46	73	93
	1963	32	48	69	90
	1958	42	62	80	94

Source: U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975).

chemical to chemical, so that the two largest producers of each of the top 100 organic intermediates--both cyclic and acyclic--total nearly 50 companies.[6] Many of these are oil companies that have integrated forward into the chemical industry.[7]

Among the over 1,250 smaller volume chemicals, roughly 60 percent have only one producer listed with the ITC.[8] While many of these compounds compete with other products when used as synthetic intermediates, they may not face competition in some of their end uses.

EMPLOYMENT

Although no complete employment statistics are available, they can be estimated through analysis of a variety of census figures. In 1977 the Industrial Organic Chemicals sector (SIC Code 2869) employed 112,000 people.[9] Within this sector miscellaneous organic chemicals accounted for 83 percent of the value of shipments.[10] Table 6 suggests comparable labor productivities (value of shipments per employee) between this industry and those that comprise the other 17 percent of shipments. Consequently, the labor force for miscellaneous organics can be estimated to be 83 percent of total employment, or 93,000.[11]

FOREIGN TRADE

The United States consistently maintains a positive balance of trade in the miscellaneous organic chemicals category. Since 1973 exports have outpaced imports by a factor of 2.1 to 3.1 (Table 7).

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[6] U.S. Department of Commerce, 1977 Census of Manufactures.

[7] Meegan, Kline Guide.

[8] U.S. International Trade Commission, Synthetic Organic Chemicals, 1977. However, previous ICF studies on pesticides indicate that ITC information on producers may not be complete.

[9] U.S. Department of Commerce, 1977 Census of Manufactures.

[10] Ibid.

[11] It is assumed that the ratio of productivities for establishments concentrating in the two aggregated "industries" during 1972 is indicative of the ratio for all establishments in these areas during 1977. The 1972 ratio is unity, so the 1977 productivities must be equal. Since the same number of employees are required to produce a given value of shipments in and out of the industry, miscellaneous organics must account for the same proportion of employment as the proportion of the value of shipments.

TABLE 6

EMPLOYMENT AND SHIPMENT VALUES FOR FIRMS CONCENTRATING IN INDUSTRIAL ORGANIC CHEMICALS

SIC Code	Employees	Value of Shipments (million of dollars)
28691	5,700	$ 378.4
28692	78,600	7,399.4
28695	3,100	152.3
Miscellaneous Organics	87,400	$7,930 1
28693	9,700	713.9
28694	3,200	462.1
Other industrial organic chemicals	12,900	$1,176.0

Source: U.S. Department of Commerce, 1972 Census of Manufactures, (Washington, D.C.: Government Printing Office, 1975).

TABLE 7

FOREIGN TRADE OF MISCELLANEOUS ORGANIC CHEMICALS

(millions of dollars)

Year	Imports	Exports
1973	223.1	696.1
1974	531.1	1,129.9
1975	453.7	1,118.5
1976	460.4	1,394.4
1977	549.3	1,452.5

Source: U.S. Department of Commerce, U.S. Imports, FT 210 and U.S. Exports, FT 610.

E-226

Synthetic Organic Dyes an Pigments

SYNTHETIC ORGANIC DYES AND PIGMENTS

OVERVIEW

This section describes the chemistry of the two major product segments of this industry and gives a brief history of the industry's development.

ORGANIC DYES

The synthetic organic dye and pigment industry had its start in England in 1856. There, William Perkin synthesized the purple dye, mauvine, by allowing the interaction of coal-tar-derived aniline with potassium dichromate and sulfuric acid. Though the synthesis was an accident, Perkin recognized its commercial potential and shortly thereafter established a plant to produce aniline dye.

Developing rapidly through Europe in the 1860s, the dye industry provided the basis for several of today's largest chemical companies, including BASF, Hoechst, Bayer, ICI, Ciba-Geigy and Sandoz. A German pioneer in dye synthesis, Friedrich Bayer, established the first U.S. aniline plant at Albany, New York in 1865.

Although domestic dye production started in 1865, during the later half of the nineteenth century the majority of dyes were imported from Germany, which then produced more than 85 percent of the world's dye sales.1/ It wasn't until 1914, when World War I caused imports to cease, that large scale manufacturing began. As a result, the vast industrial and chemical experience Germany had accumulated created strong marketing and manufacturing advantages which exist to this day.

The original use of aniline dyes was to color fabric. Success in the synthesis of dyes led to a rapid advancement of chemical knowledge in many related areas and to the development of hundreds of coal tar (aniline) based dyes. With the advent of large-scale petroleum production, entirely new classes of dyes sprang forth. Today's internationally recognized reference work, the Colour Index, lists more than 8,000 distinct dye products.2/

1/Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977), p. 155.

2/Society of Dyers and Colourists. Colour Index, Vols. 1-6 (3rd ed., Bradford, England).

Dyes can generally be classified using two different bases: application and properties, or chemical structure. The following is a brief description of the most common categories according to their characteristics of application:

- Acid dyes. Also known as anionic dyes, these dissociate in aqueous solutions to yield negatively charged colored ions. Many chemical types belong to this category, including azo, anthraquinone, azine, nitro, nitroso, and triarylmethane compounds. They are used mostly to color polymide fibers, wool, and silk. Colors generally are bright and have good fastness properties.

- Azoic dyes. These comprise a two-component system that results in deposit of an insoluble azo compound on the substrate. They are used to dye and print cellulosic fibers. particularly cotton. They usually impart hues of maroon, orange, and red. Light-fastness of the dyed fabric is extremely good.

- Basic dyes. These are also known as cationic dyes. When originally synthesized, they were used to color natural fibers. Now, a wide range of chemical types have been made that have good light-fastness characteristics on acrylic fibers. Usual hues imparted are bright orange and red.

- Disperse dyes. As the name suggests, these are applied as aqueous dispersions. being essentially insoluble in water. Compounds belong to three main chemical classes--azo, anthraquinone, and nitroarylamine. They are used widely to color man-made fibers. acrylic, cellulose acetate, polyamide, and polyester. Some are used to surface-color plastics.

- Direct dyes. These chemicals are anionic, and are used primarily with cellulosic fibers. They are applied from an aqueous solution containing an electrolyte. Dyes of this class also are used to color leather and paper.

- Mordant dyes. This class requires a mordant to fix the dye to the fiber in the form of a complex. Mordants are usually metal compounds.

- Reactive dyes. These chemicals form covalent bonds with the substrate. First introduced commercially by Imperial Chemical Industries (ICI) in 1956, they were used originally with cellulosics. Since then, compounds have been made that are suitable for coloring polymides and wool. They have good fastness properties because they are chemically linked to groups on the substrate chain.

- Solvent dyes. These are soluble in organic solvents. Principal uses are in lacquers and varnishes, printing inks, and plastics. They also are used to color cosmetics, candles, soaps, and the like. The chemicals are related to disperse dyes and are now being developed for use with polyester fibers. Solvent dyeing speeds drying time and obviates the need to grind insoluble disperse dyes to fine mill sizes.

- Sulfur dyes. These are water-insoluble compounds that contain sulfur both as an integral part of the chromophore (the group that gives rise to the color of the chemical) and are a component of polysulfide pendant chains. They are reduced to a water-soluble form before being applied to the fiber. Subsequent oxidation causes the compounds to revert to their original colored state. They are used mainly with cellulosic fibers.

- Vat dyes. Like sulfur dyes, these are insoluble in water. The reduced, water-soluble form is applied to the fiber and then oxidized to its insoluble form. A large number of chemicals belong to this class. Principal uses are the dyeing and printing of cotton, but they may be applied also to celluose acetate, silk, and wool. Vat dyes have outstanding fastness properties.[3]

Unlike many other segments of the chemical industry, the dye industry is characterized by a large number of products in terms of colors, methods of application, and the form in which they are sold to users. Many firms have over 1,000 products for sale. and Bayer offers more than 2,000.[4] As a result, unlike the inorganic pigments whose production may be measured in thousands of tons per day, the largest quantities of individual organic dyes produced each year are much smaller. Table 1 illustrates this by showing six leading individual organic pigments made from dyes produced in 1970 and 1976 in the U.S. and, as a comparison, the amounts for three of the largest inorganic pigment colorants.

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[3] General descriptions from Chemical & Engineering News, February 26, 1979.

[4] Ibid., p. 19.

TABLE 1

SALES VOLUMES OF LEADING ORGANIC PIGMENTS (FROM DYES) AND INORGANIC PIGMENTS: 1970 AND 1976

Colorant	Production (thousands of tons)	
	1970	1976
Organics		
Benzidine Yellow	4.2	6.0
Phthalocyanine Blue	3.9	5.3
Lithol Red	3.8	4.2
Phthalocyanine Green	1.7	1.7
Permanent Red 2B	1.4	1.4
Red Lake C	1.1	1.7
Inorganics		
Titanium Dioxide	655.3	711.7
Red Monoxide (Litharge)[a]	157.0	93.2
Chrome Yellow and Orange[a]	32.0	32.5

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[a] Data is for 1972 and 1977.

Sources: U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington. D.C.: Government Printing Office. 1979); Stanford Research Institute, Chemical Handbook, 1978; and U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, 1971 and 1976).

The relative maturity of the dye industry has acted to concentrate the producers both domestically and abroad. In 1976 there were 41 producers, but the four leading producers accounted for nearly 55 percent of all U.S. sales.[5] Table 2 shows the seven leading U.S. producers in 1976 and their sales volumes.

TABLE 2

MAJOR U.S. SUPPLIERS OF DYES: 1976

Rank	Company	Million of Dollars
1	DuPont	100
2	Ciba-Geigy[a]	95
3	Mobay	85
4	Sandoz[a]	75
5	Crompton & Knowles[a]	55
6	American Cyanamid	50
6	American Color & Chemical	50
	Other	140
	Total	650

[a] Sales include dyes produced by Toms River Chemical.

Source: Mary K. Meegan, Kline Guide to the Chemical Industry (3rd. ed., Fairfield, NJ: Charles Kline & Co., 1979).

Approximately two-thirds of the dyes consumed in the U.S. are used for textile application on synthetic and natural fibers. Approximately 20 percent of sales goes to the paper industry, and the remainder goes to color plastics, leather, food, and to the manufacture of organic pigments.[6] A later section will describe the production, price and sales trends, and the competitive situation.

ORGANIC PIGMENTS

Organic pigments are insoluable precipitates from dyes and organic intermediates that are applied in a liquid vehicle. The two most common varieties are lakes (originally, pigments derived from lac dyes), which are organic dyes precipitated on an inorganic substrate, and toners, which are full-strength organic pigments with no inorganic diluent. Because pigments are insoluable, their application technology is different from dyes, even though they are derived from organic dyes.

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[5] Meegan, Kline Guide, p. 158.

[6] Meegan, Kline Guide; and Stanford Research Institute, Chemical Handbook, 1978.

Because organic pigments are essentially a subset of the organic dye industry, their development closely parallels that of the larger dye segment. Like dyes, pigment production is concentrated. There were 33 producers of pigments in 1976, with the four largest producers supplying 48 percent of sales in that year.[7]

The majority of organic pigments are used in printing inks, accounting for 47 percent of total sales in 1977. Paints follow closely with 33 percent of sales. Unlike the organic dyes, sales of pigments are concentrated with six individual colors constituting over 55 percent of sales. These individual products as well as the volumes and amounts of total U.S. production will be discussed in detail in the next section.

RAW MATERIALS, PRODUCTION AND PRICES

As their name implies, organic dyes and pigments are produced from organic raw materials, most notably petroleum derivatives. Because of the large number of products and relatively small quantities of each product, batch processing is widely used. Producers are highly subject to changes in textile fashions, and are called upon to produce new hues annually. For example, ICI's manager of dye production stated recently that half of ICI's present synthetic organic colorants were not available 10 years ago, and the company introduced several significant new products just within the last 18 months. The level of product innovation is quite high although few patents are issued on them because of the short market life span for the majority of products.[8] Because the products are sold based on performance rather than what they contain, there is a great deal of product differentiation and industrial secrecy concerning their formulation. As a result, public data is not available concerning the types and amounts of feedstocks that are consumed for dyes and organic pigments.

As previously mentioned, the sale of dyes is closely tied to the sales of textiles. Figure 1 illustrates the relationshp between dye and textile sales for the years 1960 to 1975.

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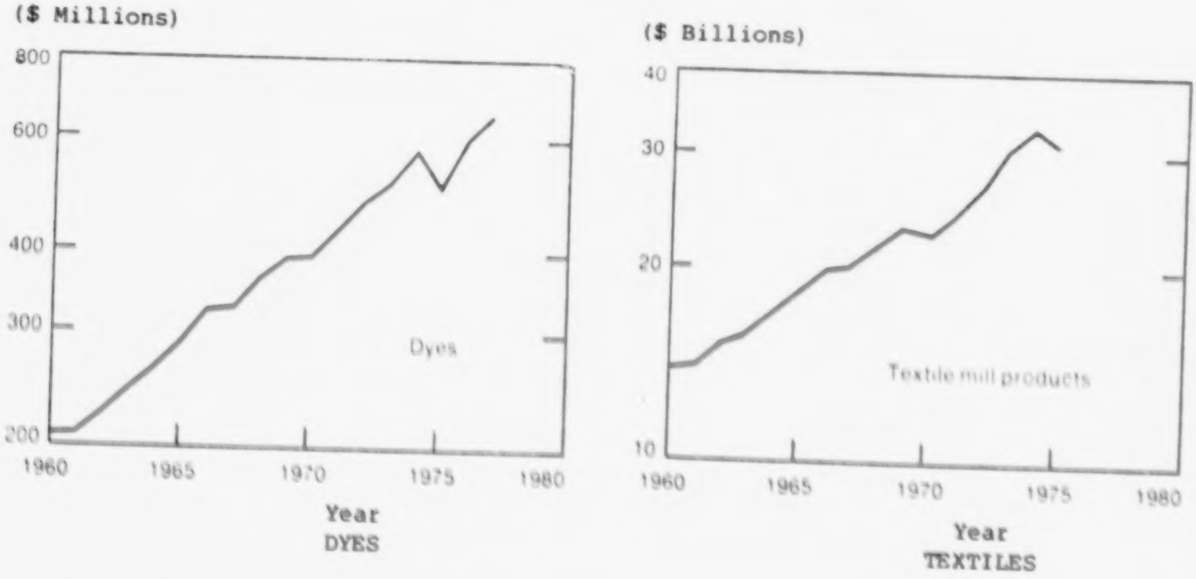
[7] These four were: DuPont, Chemetron, American Cyanamid, and Sun Chemical (Meegan, Kline Guide).

[8] Chemical and Engineering News, February 26, 1979.

FIGURE 1: U.S. SHIPMENTS OF DYES AND TEXTILES, 1960-1975



Source: U.S. Department of Commerce, Bureau of the Census, Survey of Current Business various years; and U.S. International Trade Commission, Synthetic Organic Chemicals, 1976 (Washington, D.C.: Government Printing Office, 1976).

Table 3 illustrates the dollar amounts of dyes and pigments sold from 1967 through 1977. During this period synthetic fibers increased their market share of all fibers sold. Because synthetic fibers require more expensive dyes, dollar sales in the 1960s and 1970s grew faster than volume. The future should see a slowing of growth in synthetic fibers, and thus, a slower growth for dyes.[9] While the sales volumes of organic pigments is smaller, their projected growth rate is larger due to a wider use by differing industries.

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[9] Meegan, Kline Guide.

TABLE 3

U.S. SHIPMENTS OF DYES: 1967-1977

Year	Total Organic Pigment Shipments (millions of dollars)	Total Dye Shipments[a] (millions of dollars)
1967	162	326
1968	189	360
1969	199	389
1970	169	397
1971	178	435
1972	225	474
1973	273	510
1974	333	573
1975	304	499
1976	410	650
1977	445	690
1980[b]		745
1985[b]		840

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[a] Includes interplant transfers.
[b] Estimates.

Sources: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years); U.S. Department of Commerce, Bureau of Census, 1967 Census of Manufactures (Washington, D.C.: Government Printing Office, 1970); U.S. Department Commerce, Bureau of Census, Annual Survey of Manufactures (Washington, D.C.: Government Printing Office, various years); and estimates by Charles Kline & Co.

As previously mentioned, sales of organic pigments are much more concentrated than dyes. Table 4 gives a breakdown of the largest volume sales by type of pigment.

The pressure of increased raw material costs after 1971 has pushed organic dye prices upwards. Table 5 illustrates the price indices for the eleven major dye categories for the years 1967 to 1976. In 1972 average prices were only 12.8 percent higher than they were five years earlier. They were 31 percent higher in 1976 than in 1972. Raw material costs have continued to increase since then, and it is expected that prices will rise dramatically.

TABLE 4

U.S. PRODUCTION AND SHIPMENTS OF ORGANIC PIGMENTS BY TYPE: 1974, 1975, and 1976

	Production (millions of pounds)			Production (millions of dollars)		
	1974	1975	1976	1974	1975	1976
Toners						
Red						
Lithol Red R	6.0	5.2	6.1	10.2	11.2	10.2+
Permanent Red 2B	2.6	2.2	2.9+	8.4	6.6	9.8+
Lake Red C	3.7	2.7	3.3	7.7	6.3	7.2
Toluidine	2.2	1.7	2.2	5.3	4.3	5.7
Eosin	1.6	--	--	--	--	--
Lithol Red 2G	1.7	1.9	2.2	5.3	5.6	--
Lithol Rubine B	1.6	1.5	2.5	4.6	5.0	--
Naphthol reds	1.1	10	1.3	4.8	4.7	6.4
Other	3.7	3.9	5.1	25.5	21.9	42.8
Subtotal	24.2	20.1	25.6	71.8	65.5	90.3
Blue						
Phthalocyanine	11.1	7.0	10.6	39.3	28.1	43.1
Other	4.4	2.4	3.6	12.3	11.7	13.6
Subtotal	15.5	9.4	14.2	51.6	39.8	56.7
Yellow						
Benzidines	13.9	8.6	12.0	33.6	20.8	27.7
Hansa	3.4	1.9+	3.2	6.2+	6.4+	10.0+
Other	1.5	1.1	1.8	9.8	9.1	12.4
Subtotal	18.8	11.6	17.0	49.6	36.3	50.1
Green						
Phthalocyanine	3.3	2.3	3.3	16.2	11.7	17.7
Other	0.7	0.4	0.5	3.8	2.6	4.0
Subtotal	4.0	2.7	3.8	20.0	14.3	21.7
Violet	2.9	2.2	3.0	22.2	20.0	28.6
Orange	1.9	1.4	1.9	7.2	5.0	8.5
Black and Brown	0.3	0.3	0.5	0.5	0.9	0.8
Subtotal	5.1	3.9	4.4	29.9	25.9	37.9
Lakes						
Red	0.5	0.3	0.4	1.6	1.1	1.4
Blue	a	1.1	0.7	a	2.3	2.1
Other	1.8	0.5	0.6	3.4	0.5	0.9
Subtotal	2.3	1.9	1.7	5.0	3.9	4.4
GRAND TOTAL	69.9	44.6	67.7	227.9	185.8	261.1

+Plus additional amounts.

a/ Included in other.

Source: Mark K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 5

INDICES OF AVERAGE MANUFACTURERS' PRICES OF SYNTHETIC ORGANIC DYES: 1967-1976

1967 = 100

Textile types[a]	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Vat	100.0	108.6	108.2	101.3	96.9	104.3	113.0	112.0	120.4	136.5
Disperse	100.0	99.2	101.2	104.5	117.0	113.8	109.3	123.1	138.9	153.8
Direct	100.0	104.6	104.6	109.9	113.2	113.2	110.6	128.5	131.8	165.1
Acid	100.0	105.0	109.1	106.3	113.6	115.8	115.8	132.6	137.6	146.1
Basic	100.0	103.1	110.4	105.8	110.0	105.8	103.1	109.3	119.7	129.0
Azoic[b]	100.0	101.5	103.1	108.4	115.4	123.3	120.7	146.4	146.5	132.0
Reactive	100.0	102.8	100.9	100.7	82.3	100.7	103.5	109.7	118.4	126.6
Mordant	100.0	96.0	100.6	97.5	108.1	93.2	--	164.6	178.3	203.1
Weighted Average	100.0	106.6	110.6	110.4	118.1	121.4	124.8	136.5	144.6	159.5
Optical brighteners	100.0	87.5	79.8	78.8	73.6	66.8	64.9	61.1	76.4	70.1
Solvent	100.0	105.3	102.4	104.1	104.1	110.0	121.8	142.4	165.3	180.4
Food, drug, cosmetic	100.0	102.7	98.4	97.5	106.3	117.9	122.0	170.1	175.8	170.5
Weighted Total	100.0	103.5	105.3	104.5	110.0	112.8	116.8	126.3	137.7	148.5

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[a] Excludes sulfur and miscellaneous textile dyes.

[b] Includes fast color bases and salts.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

During this same period, the trade balance of organic dyes has been decidedly negative, with 75 percent of imports in 1976 coming from Germany and Switzerland[10] (see Table 6). In 1977 DuPont dropped its vat dye line after losses of $25 million (pretax) on sales of $105 million. In 1978 it continued with unspecified losses on $85 million in sales. In June 1979 DuPont announced a total withdrawal from the market, leaving American Cyanamid as the only American producer.[11] It is estimated that the trade balance will continue to deteriorate.

TABLE 6

U.S. IMPORTS AND EXPORTS OF SYNTHETIC ORGANIC DYES: 1969-1965

(millions of dollars)

Year	Imports	Exports	Trade Balance
1969	63	21	-42
1970	70	29	-41
1971	97	29	-68
1972	101	34	-67
1973	100	57	-43
1974	106	84	-22
1975	80	61	-19
1976	132	77	-55

Source: U.S. Department of Commerce, U.S. Imports, FT 135; and U.S. Exports, FT 410.

Unlike the dyes segment, synthetic organic pigments enjoy a slightly positive foreign trade balance, and may continue to do so.[12] Table 7 shows the history of foreign trade in organic pigments from 1969 through 1977.

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[10] Stanford Research Institute, Chemical Handbook, 1978.

[11] Chemical and Engineering News, June 11, 1979.

[12] U.S. Department of Commerce. 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

TABLE 7

U.S. IMPORTS AND EXPORTS OF SYNTHETIC ORGANIC PIGMENTS: 1969-1976

(millions of dollars)

Year	Imports	Exports	Trade Balance
1969	--	12.0	--
1970	12.4	14.3	1.9
1971	14.7	16.2	1.5
1972	15.0	19.2	4.2
1973	21.2	29.1	7.9
1974	31.7	33.1	1.4
1975	25.4	25.1	-.3
1976	32.3	36.5	4.2
1977	36.0	36.0	0.0

Source: U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

COMPETITION AND INNOVATION

Rapid expansion of production facilities both domestically and abroad in the late 1960s and early 1970s, coupled with large price increases and a depressed textile market in the middle 1970s, have created at present an overcapacity in organic dyes.[13] This has led to price cutting, exits from the industry by large producers, and for some, such as DuPont, large losses prior to exit. Foreign competitors claim that because U.S. dye managers are more geared to mass production at high volume, they have less flexibility to develop new products to support flagging sales during the cyclical downswings of the textile industry.[14]

Coupled with this problem is the emergence of more stringent environmental regulations regarding waste products. As a result, the Dyestuffs Environmental and Toxicology Organization (DETO) was formed in 1977. Each member company provides funds and key personnel to DETO to conduct studies on toxicology and ecology. While there is no publicly available data, it is reasonable to assume this will add to overall manufacturing costs and may result in delaying or deferring the introduction of some new dyes and pigments. This may lower innovation in this segment, which is already quite low.

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[13] Chemical and Engineering News, February 26, 1979.

[14] Ibid., p. 20.

Plasticizers

PLASTICIZERS

DESCRIPTION

Plasticizers are organic chemicals which are physically incorporated into vinyl and other polymers, either to improve workability during fabrication or to increase flexibility in the end-use products. The first plasticizer was used in the 1860s, but the modern plasticizer industry really began with the development of polyvinyl chloride (PVC) plastic in the 1920s and 1930s; the production of PVC now constitutes about two-thirds of all plasticizers consumed in the U.S. About 85 percent of all plasticizers are used in the plastics industry, and most of the rest is used in the production of rubber and cellulose products.

USES OF THE CHEMICAL

Plasticizers are by definition intermediate products, being consumed in the production of end-use chemical products. Polyvinyl chloride, which consumes about two-thirds of plasticizer production, has a wide variety of uses, as shown in Table 1. Flooring, wire and cable coating, wrapping films, textile and paper coatings, and moldings and extrusions are all important uses.

TABLE 1

CONSUMPTION OF PLASTICIZERS IN PVC: 1975

Application of PVC	Amount of Plasticizers of pounds)
Film and sheet	244.3
Flooring	164.0
Molding and extrusion	178.4
Textile and paper coating	147.0
Wire and cable coating	169.5
Others	174.2
Total	1,077.4

Source: "Plasticizers." Modern Plastics, September 1975, p. 47.

There are no natural substitutes for plasticizers themselves although there are substitutes for the end-use products.

RAW MATERIALS

Plasticizers are produced from a number of chemical intermediates. Their production consumes a miniscule percentage of the supply of most of these intermediates. However, plasticizer production does account for about 50 percent of the use of phthalic anhydride, from which about two-thirds of all plasticizers are produced.

PUBLIC DATA

Table 2 displays the quantities of plasticizers produced and their relation to the production of PVC, the major consumer of plasticizers. In 1978 more than two billion pounds of plasticizers, selling for more than $800 million, were produced. There has been a long-term increase in production of both plasticizers and PVC. Although the 1975 recession proved devastating for both, production has since recovered.

As shown by the steady decrease in the ratio of plasticizer production to PVC production, the output of plasticizers is growing much more slowly than the output of PVC. This is due to the increased proportion of PVC being used for rigid end-products, which consumes less plasticizer than PVC used for flexible end-products.1/

Table 3 displays a more detailed breakdown of plasticizer production during the 1960s and 1970s. There are few substantial changes between 1961 and 1976. Phthalic anhydride esters continue to hold over 60 percent of the market, with di(2-ethylhexyl) phthalate as the most important single product. The complex polymers, which are substitutes for traditional plasticizers, hold about three percent of the market.

Imports are a negligible component of U.S. consumption, amounting to only 6.2 million pounds in 1977, 0.4 percent of domestic consumption.2/ Exports account for a significant amount of U.S. production: in 1977 the U.S. exported 152.5 million pounds of plasticizers worth $50.8 million. These exports were 8.5 percent of the U.S. volume and about 7 percent of the value of U.S. sales (see Table 4). In recent years, exports have been declining in importance; in 1972 they equalled 9.9 percent of production volume and 10.6 percent of production value. and in 1967 they equalled 11.7 percent of volume and 21.9 percent of value.

1/Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 89.

2/U.S. International Trade Commission, Synthetic Organic Chemicals, 1977 (Washington, D.C.: Government Printing Office, 1977), p. 254.

TABLE 2

PRODUCTION OF PLASTICIZERS AND POLYVINYL CHLORIDE (PVC)

Year	Plasticizer Production (millions of pounds)	Polyvinyl Chloride (PVC) Production (millions of pounds)	Ratio of Plasticizer Production to PVC Production
1978	2,086	5,878	.35
1977	1,792	5,267	.34
1976	1,699	4,545	.37
1975	1,352	3,695	.37
1974	1,892	4,774	.40
1973	1,873	4,594	.41
1972	1,708	4,322	.40
1971	1.494	3,437	.43
1970	1,336	3,115	.43
1969	1,382	3,032	.46
1968	1,331	2,635	.51
1967	1,263	2,142	.59
1966	1,209	2,164	.56
1965	1,073	1,838	.58
1964	951	1,637	.58
1963	835	1,386	.60
1962	781	1,215	.64
1961	630	977	.64

Source: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office. various years).

TABLE 3

PLASTICIZER PRODUCTION, SELECTED YEARS

	1976		1971		1966		1961	
	Volume (millions lbs.)	Percent of Total	Volume (million lbs.)	Percent of Total	Volume (million lbs.)	Percent of Total	Volume (millions lbs.)	Percent of Total
Total	1,587.4	100.0	1,494.0	100.0	1,208.9	100.0	629.7	100.0
Cyclic	1,185.9	74.7	1,130.4	75.7	897.2	74.2	473.6	75.2
Phosphoric acid esters	74.9	4.7	91.4	6.1	68.6	5.7	47.0	7.5
Cresyl diphenyl phosphate	4.5	0.3	20.4	1.4	20.0	1.7	13.0	2.1
Phthalic anhydride esters	1,042.9	65.7	978.2	65.5	754.5	82.4	376.5	59.8
Dibutyle phthalate	13.7	0.9	23.0	1.5	20.2	1.7	5.6	0.9
Diethyl phthalate	16.1	1.0	16.9	1.1	21.5	1.8	17.3	2.7
Diisodecyl phthalate	143.1	9.0	135.7	9.0	103.3	8.5	48.3	7.7
Dimethyl phthalate	8.8	0.6	10.6	0.7	4.4	0.4	4.1	0.7
Dioctyl phthalates	314.0	19.8	437.3	29.3	376.8	31.2	181.5	28.8
Di(2-ethylhexyl) phthalate	296.7	18.7	386.3	25.9	253.0	20.9	138.3	22.0
Di-tridecyl phthalate	10.5	0.7	20.3	1.4	19.4	1.6	2.7	0.4
Acyclic	401.5	25.3	363.6	24.3	311.7	25.8	156.1	24.8
Adipic acid esters	59.6	3.8	63.4	4.2	51.8	4.3	25.7	4.1
Di(2-ethylhexyl) adipate	39.3	2.5	35.1	2.3	22.3	1.8	8.5	1.3
Complex linear polyesters & polymers	52.9	3.3	46.2	3.1	47.9	4.0	16.5	2.6
Epoxidized esters	117.4	7.4	99.0	6.6	86.6	7.2	15.9	2.5
Oleic acid esters	9.9	0.6	12.5	0.8	10.4	0.9	8.9	1.4
Phosphoric acid esters	25.7	1.6	22.7	1.5	13.6	1.1	10.6	1.7
Sebacic acid esters	1.7	0.1	9.6	6.4	12.6	1.0	11.5	1.8
Stearic acid esters	12.1	0.8	11.8	7.[illegible]	7.[illegible]	0.6	7.4	1.2

Source: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

TABLE 4

PLASTICIZER EXPORTS

	Plasticizers except Cyclic	Dioctyl Phthalates	Phthalic Anhydride Esters, NEC	Cyclic Plasticizers, NEC	Total	Percent of Total Production
1977	54.8	9.7	83.9	4.1	152.5	8.5
1976	48.1	29.9	75.5	10.0	163.5	9.6
1975	31.8	20.3	50.9	8.6	111.6	8.3
1974	50.6	23.7	69.3	12.7	156.3	8.3
1973	58.3	14.6	78.4	10.7	162.0	8.6
1972	36.3	16.8	105.8	10.4	169.3	9.9
1971	32.9	14.6	47.6	8.1	103.2	6.9
1970	24.0	36.0	36.5	8.5	105.0	7.9
1969	21.3	14.3	107.7	7.1	150.4	10.9
1968	19.2	25.1	89.4	6.2	139.9	10.5
1967	17.0	22.9	101.2	6.8	147.9	11.7
1966	14.0	15.9	79.3	5.6	114.6	9.5
1965	11.7	23.5	83.0	3.9	122.1	11.4

NEC - not elsewhere classified.

Source: U.S. Department of Commerce, U.S. Exports: Commodity by Country, FT 410, various years.

Table 5 displays the average price for all plasticizers produced. During the late 1950s the prices of plasticizers dropped and continued an overall decline until 1943 when they started to rise. In the inflationary environment of 1974 they increased sharply and continued to rise more slowly in the late 1970s. The price declines correspond to declines in the price of phthalic anhydride, the raw material for the phthalic anhydride esters, the most important plasticizer. Table 6 presents the prices of a number of phthalate anhydride derivates during this period. Each of the products' prices shows the same trends as the prices of the entire group and of phthalic anhydride.

COMPANIES IN SEGMENT

There are more than 50 producers of plasticizers; the Census of Manufactures lists 49 firms with shipments of $100,000 or more in 1977 and the U.S. International Trade Commission lists 54 in 1976. In 1961 the ITC listed 53 firms in the industry and the number remained virtually constant during the 1960s and 1970s. The stability in the number of firms in the industry, combined with the reduction in the number of firms producing each product discussed earlier, suggests that these firms are becoming more specialized. It appears that most of the producers are large, diversified corporations or subsidiaries thereof, and plasticizers compose only a tiny fraction of their business. Therefore, it seems impossible to estimate the profitability of this sector from the limited information available.

Mergers and acquisitions have helped change the roster of producers over the years. Monsanto, W.R. Grace, Rohm & Haas, FMC, and Eastman were among the leading producers in both the early 1960s and the late 1970s. But Allied Chemicals and Celanese. both among the leading producers in the early 1960s, no longer produce plasticizers, and Union Carbide no longer produces phthalate derivatives. U.S. Steel, Exxon, Stauffer, Tenneco, and BASF Wyandotte have become major plasticizer producers, either by buying small producers and expanding, or by beginning production from scratch.[3]

An examination of more narrowly defined markets also reveals some turnover among the leading firms. In the phthalate markets, Monsanto, Grace, and Eastman have remained leaders, but Union Carbide and Allied Chemical have dropped out and Exxon and BASF Wyandotte have entered. Union Carbide and Rohm & Haas have remained leading producers of epoxidized esters, Witco has entered, and Swift and Archer-Daniels-Midland have dropped out. FMC and Monsanto remain leading phosphate ester producers, Stauffer has entered the market, and Celanese has dropped out.[4]

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[3] Comparisons made between Meegan, Kline Guide and Chemical and Engineering News, November 13, 1961, pp. 134-5.

[4] Comparisons made between Chemical and Engineering News, November 13, 1961, pp. 134-135, and "Additives for Plastics - Plasticizers", Plastics Engineering, January 1977, pp. 32-38.

TABLE 5

PLASTICIZER PRICES

Year	Price of Plasticizers (dollars per pound)	Price of Phthalic Anhydride (dollars per pound)
1978	.40	
1977	.38	.23
1976	.39	
1975	.35	.21
1974	.31	
1973	.20	
1972	.18	
1971	.16	
1970	.19	.09
1969	.21	
1968	.23	
1967	.22	
1966	.21	
1965	.21	.08
1964	.21	
1963	.22	
1962	.25	
1961	.29	
1960	.30	.18
1959	.30	
1958	.31	
1957	.31	
1956	.32	
1955	.31	.19

Source: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

TABLE 6

PRICES OF PHTHALIC ANHYDRIDE DERIVATIVES: SELECTED YEARS

(dollars per pound)

	1956	1961	1966	1971	1976
Phthalic Anhydride esters	.29	.25	.16	.13	.30
Dibutyl phtalate	.26	.27	.19	.16	.37
Diethy phtalate	.25	.24	.18	.18	.42
Diisodecyl phthalate	.29	.24	.15	.12	.29
Dimethy phthalate	.26	.25	.20	.20	.37
Dioctyl phthalates	.28	.23	.14	N/A	.26
Di(2-ethyhexyl) phthalate	.28	.24	.14	.11	.26
Di-tridecyl phthalate	N/A	.29	.22	.19	.35

N/A - not available.

Source: U.S. International Trade Commission. Synthetic Organic Pesticides (Washington, D.C.: Government Printing Office, various years).

The Kline Guide to the Chemical Industry estimates that in 1976, the leading four firms produced just over 50 percent, and the leading eight firms produced just over 70 percent of all plasticizers. There is not much captive production of plasticizers (somewhat less than 10 percent), so the vast majority is traded on the market. In 1961, Chemical Engineering News estimated the four-firm concentration ratio at about 35 to 40 percent and the eight-firm ratio at about 55 to 60 percent.[5] It appears that concentration has increased slightly, but the difference may be due simply to different methods of estimation.

As usual, the more narrowly defined the market, the higher the concentraton ratios. The 1961 Chemical and Engineering News data yields estimates for narrower markets that are lower than the estimates for the more broadly defined markets. As can be seen in Table 7, the markets which are larger and more inclusive (phthalates, the combined market) are less concentrated than the smaller markets. When we descend to the level of individual products. production is more concentrated still. Most products are made by three or fewer firms, though the more popular ones are manufactured by a greater number. There has been a reduction in the number of firms making individual products over time. For example, of the 15 phthalic anhydride derivatives listed in both 1961 and 1976, 12 were produced by fewer firms in 1976, and the other three were produced by the same number. Di(2-ethylhxyl) phthalate, the single product with the greatest production volume in both 1961 and 1976, went from 18 producers in 1961 to 11 in 1976.

During the 1960s. there was an increasing trend toward backward integration from plasticizers into the alcohols and phthalic anhydride, from which plasticizers are made. Before 1960 such integration was rare but by 1970 most of the large producers made either alcohols, phthalate anhydride, or both.

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[5] Derived from data presented in Chemical and Engineering News, November 13, 1961. Estimates were obtained by aggregating the three tables on pages 134-135. These estimates cover only about 75 percent of the entire market. Note that the true concentration ratio for the entire market is probably lower still.

TABLE 7

ESTIMATED CONCENTRATION RATIOS IN PLASTICIZER MARKETS: 1961

Market	Four-Firm Ratio	Eight-Firm Ratio	Percent of Total Plasticizer Production
Phthalates[a]	40-45%	60-65%	59.8%
Polymeric	63-71	84-88	2.6
Epoxidized	66-68	85-87	2.5
Phosphate esters	70-75	95-96	9.3
Total	35-40%	55-60%	74.3%

Note: The data given in the source refers to production capacity. The concentration ratios are constructed by assuming that all producers use about the same percentage of their capacities during the year.

[a] Phthalate capacity can also be used to make adipates, sebacates, azelates, and other monomeric plasticizers.

Source: Chemical and Engineering News, November 13, 1961, pp. 134-135. The data in the last column, "Percent of Total Production" is taken from U.S. International Trade Commission, Synthetic Organic Pesticides (Washington, D.C.: Government Printing Office, 1961).

INNOVATION

We believe that the consensus among trade journal articles is that considerable innovation exists in the plasticizer industry. One recent article states that in 1934, 56 different plasticizers were commercially available, of which eight are still produced. In 1943, 150 were in use, of which 60 remain in use today. By the mid 1960s, 300 products were available, and by the mid 1970s, 500 were available.[6] There have been a particularly large number of new polymeric plasticizers introduced in recent years.

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[6] "Additives for Plastics - Plasticizers", Plastics Engineering, January 1977, pp. 32-38.

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Rubber-Processing Chemicals

RUBBER-PROCESSING CHEMICALS

DESCRIPTION

Rubber-processing chemicals include a wide variety of substances that are used to modify rubber so it can be used in commercial applications. Rubber-processing chemicals have been in use since the 1840s, when the development of vulcanization (treating rubber with sulfur) by Charles Goodyear greatly improved the properties of rubber and expanded its markets. The early twentieth century saw the beginning of the development of a wide variety of rubber-processing chemicals. Today there are more than 20 different types of chemicals and over a thousand products used to process natural rubber and the many types of synthetic rubber.

USES

There are many different varieties of rubber-processing chemicals which are designed to prevent the deterioration of rubber and modify its properties. Not all of the chemicals which are used in rubber production are included in this category; such products as sulfuric acid, salt, alum, sulfur, zinc oxide, fatty acids, silicas, clays, carbon black, nylon, rayon, and pigments have many uses outside the rubber industry, and, therefore, are not discussed here. The major categories of rubber processing chemicals that are included here are:

- Accelerators. Accelerators cause rubber to vulcanize faster and they often retard aging. The first accelerators, aniline derivatives, were developed during the first decade of this century. Thiazole compounds, which today account for about two-thirds of accelerator production, were first developed during the 1920s.

- Activators. Activators increase the efficiency of vulcanization. Zinc oxide is the most widely used activator. Fatty acids, fatty acid amines, and zinc stearate are also used as activators.

- Antioxidants. Antioxidants protect rubber from deterioration due to the action of oxygen and oxidizing chemicals. In the nineteenth century the rubber industry used a variety of naturally occurring materials to retard oxidation, including cresote, naphthalene, asphalt, and coal tar pitch. The accelerators developed early in the twentieth century also protected rubber against oxidation, and replaced the earlier substances. In the 1920s the first nonaccelerating antioxidants, which made rubber last about 67 percent longer than earlier antioxidants, were developed, and from then until World

War II there was a burst of innovation in antioxidants. After the war a whole new class of antioxidants which did not discolor rubber was developed. Both discoloring and non-discoloring antioxidants are used today; the discoloring antioxidants are generally more effective at preventing deterioration.

- Antiozonants. During World War II it was discovered that ozone also ages some synthetic rubber products quite rapidly, although other synthetic rubbers are more resistant. A number of effective antiozonants were developed during the 1950s, and in addition to protecting rubber from ozone, they help protect against oxygen, prevent cracking, and deactivate metallic impurities which can weaken the rubber.

Although these four are the major categories, there are many other types of chemicals used in rubber-processing; in 1958, 28 different types were listed in one trade journal. Many of the antioxidants and antiozonants used primarily in rubber processing are used for the same purposes in plastics, petroleum products, and food. About 70 percent of the antioxidants and antiozonants are used in rubber products.

PUBLIC DATA

Table 1 displays data on U.S. production of rubber-processing chemicals for the period 1961 to 1978.

As can be seen, production shows a long term increase over the period covered, with surges during periods of economic expansion and reductions in growth or actual declines during periods of recession (1969 to 1970, 1974 to 1975). The production of rubber-processing chemicals is dependent on the production and use of both synthetic and natural rubber as well as on general economic conditions. Table 2 displays the U.S. production of synthetic rubber and imports of natural rubber. The fluctuations in production of rubber seem to be about as close to fluctuations in production of rubber-processing chemicals as possible, given the changes in inventories and imports for which we have no data. There does seems to be a long-term decrease in the volume of rubber-processing chemicals used per unit of rubber, which may be attributable to technological improvements (although more data on imports and inventories could possibly contradict this observation). Table 3 displays the value and the production volume of exports of rubber-processing chemicals, and the volume of exports as a percentage of total production volume. During this decade exports as a percentage of production have risen steadily, exceeding 20 percent in both 1976 and 1977.

TABLE 1

PRODUCTION OF RUBBER-PROCESSING CHEMICALS

Year	Volume (millions of pounds)	Average Price (dollars per pound)
1978	365.8	1.26
1977	402.2	1.23
1976	384.4	1.10
1975	279.0	1.02
1974	383.9	.83
1973	400.9	.64
1972	361.0	.63
1971	323.5	.65
1970	298.3	.65
1969	303.5	.63
1968	312.6	.64
1967	264.1	.68
1966	283.3	.66
1965	251.9	.64
1964	260.6	.67
1963	233.6	.67
1962	228.4	.66
1961	205.1	.67

Source: U.S International Trade Commission Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

TABLE 2

PRODUCTION OF RUBBER PROCESSING CHEMICALS AS A PERCENTAGE OF RUBBER PRODUCTION

Year	Domestic Consumption of Rubber-Processing Chemicals[a] (millions of pounds)	Domestic Production of Rubber[b] (millions of pounds)	Rubber-Processing Chemicals as Percentage of Rubber
1977	323.9	7588.2	4.3
1976	306.3	6982.7	4.4
1975	229.5	6049.5	3.8
1974	323.7	7268.1	4.5
1973	332.2	7430.1	4.5
1972	318.8	6262.8	5.1
1971	277.0	5988.6	4.6
1970	254.2	5669.6	4.5
1969	267.1	5835.2	4.6
1968	271.4	5478.1	5.0

a/ Domestic consumption equals production minus exports. Adjustments for imports and changes of inventory could not be made because of the unavailability of data.

b/ Production of rubber is the sum of synthetic rubber production and natural rubber imports; the latter is presumably processed in the United States.

Source: Production: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

Exports: U.S. Department of Commerce, Exports: Commodity by Country, FT 410, various years.

Imports: U.S. Department of Commerce, U.S. General Imports: Commodity by Country, FT 135, various years.

TABLE 3

EXPORTS OF RUBBER PROCESSING CHEMICALS

Year	Exports (millions of dollars)	Exports (millions of pounds)	Export Volume as Percentage of Total Production
1977	59.5	73.4	20.6
1976	67.3	78.1	20.3
1975	45.8	49.5	17.7
1974	38.8	60.2	15.7
1973	37.9	68.7	17.1
1972	25.5	42.2	11.7
1971	27.4	46.5	14.4
1970	25.4	44.1	14.8
1969	21.6	36.4	12.0
1968	24.6	41.2	13.2

Source: U.S. Department of Commerce, Exports: Commodity by Country, FT 140, various years.

The Census of Manufactures does not provide concentration ratios for this sector, but something can be said about the degree of concentration in the industry by piecing together information from several sources. The Census of Manufactures states that in 1977 there were 31 firms producing rubber-processing chemicals and in the same year the International Trade Commission lists 23 firms.[1] Four of the producers listed by the USITC are major synthetic rubber manufacturers (B.F. Goodrich, Uniroyal, DuPont and Goodyear) which produce rubber-processing chemicals for their own use. As shown in Table 4, captive production may be related to the exit of Union Carbide from the industry after 1975. If Union Carbide sold its rubber-processing chemical business to one of the rubber producers, there would be an explanation for the increase in captive production. However, inspection of Union Carbide's annual reports during this period shows no such sale. According to the USITC, Goodyear, Goodrich, DuPont and Uniroyal must share at least 40 percent of production. However, there is no other available information on the shares of production held by other firms. The Kline Guide to the Chemical Industry states that the four firms, along with American Cyanamid, Monsanto, Pennwalt, and Vanderbilt, dominate the market, with Goodrich, Goodyear, and Uniroyal producing about 50 percent of the total. One should note that the synthetic rubber industry is itself highly concentrated, with a four-firm concentration ratio of 54 percent and an eight-firm ratio of 73 percent in 1972.[2] The high degree of concentration among buyers should negate the advantage that a high degree of concentration usually gives sellers.

As one begins to look at markets that are more precisely defined than "rubber processing chemicals" one finds the markets to be more concentrated. There are only one or two producers of the vast majority of rubber-processing chemicals, although any given chemical meets competition from other chemicals.

In recent years, the number of firms producing rubber-processing chemicals seems to have been decreasing, falling from 31 in 1969 to 21 in 1978, according to the International Trade Commission. Allied Chemical and General Tire are two large firms that left the industry during that period. Yet, over the last two decades, there also appears to have been a slight decrease in the number of firms that produce specific chemicals in general.

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[1] One possibility is that some firms do not report to the International Trade Commission. This might account for the apparent long-run decline in rubber-processing chemicals as a percentage of rubber production mentioned above. One indication that the ITC list is not comprehensive is that Uniroyal, absent in 1975 to 1976, is present in 1969 to 1974 and 1977 to 1978. It seems more plausible that Uniroyal would have failed to submit information for two years, as opposed to halting production for two years.

[2] U.S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures, (Washington, D.C.: Government Printing Office, 1975).

TABLE 4

PERCENT OF PRODUCTION OF RUBBER-PROCESSING CHEMICALS USED INTERNALLY BY PRODUCER

Year	Percent of Production
1978	37.5
1977	40.8
1976	41.7
1975	26.9
1974	25.4
1973	22.2
1972	22.4
1971	23.9
1970	23.6
1969	24.4
1968	24.5
1967	24.0
1966	26.1
1965	23.1
1964	29.3
1963	24.2
1962	24.6
1961	24.1

Note: The percent of captive production was determined by dividing "production sales" by production.

Source: U.S. International Trade Commission, Synthethic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

The price data in Table 1 show that the price pattern of rubber-processing chemicals looks much like the price patterns of other petrochemicals--stability during the 1960s and early 1970s, and sharp price increases in the mid-1970s as a result of the rise in oil prices. But not all chemical prices conform to the overall trend. As shown in Table 5, the prices of all the products and categories did jump during the mid-1970s, but during the 1960s there were a number of chemicals whose prices were not stable. In particular, the cyclic dithiocarbamic acid derivatives increased in price by about 60 percent between 1961 and 1971, while the acyclic dithiocarbamic acid derivatives decreased by about 20 percent.

COMPANIES IN SEGMENT

The number of companies making rubber-processing chemicals and the identities of the leading producers were discussed above. With few exceptions rubber-processing chemicals are just one small part of each firm's business, so no conclusions can be drawn about their profitability. The few exceptions appear to be closely held firms, since no data on them is available from the Standard and Poor's Indices.

INNOVATION

We believe that, through 1960, there was a great deal of development of new rubber-processing chemicals. As discussed earlier, the 1940s and 1950s saw a host of new antioxidants introduced and the introduction of a major new category of rubber processing chemicals, the antiozonants. One industry source states that in 1930, there were 12 different types of rubber-processing chemicals with 203 distinct products; in 1940 there were 14 different types featuring 246 different products, but by 1958 there were 28 different types of rubber-processing chemicals encompassing 1,274 distinct products.[3] There is no quantitative information currently available to indicate the degree of innovative activity in the industry during the last twenty years. However, there has been substantial innovation in the area of specialty elastomers, and a large portion of this innovation may have resulted from the development of new rubber-processing chemicals.

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[3] "Rubber Chemicals: Growth with Stability," Chemical Engineering, June 16, 1958, pp. 84-86.

TABLE 5

PRICES OF RUBBER PROCESSING CHEMICALS

(dollars per pound)

	Year			
	1961	1966	1971	1976
Cyclic Chemicals				
Accelerators, activators, & vulcanizing agents	.62	.60	.61	1.04
Aldehyde-amine reaction products	.89	1.06	.91	1.66
Dithiocarbamic acid derivatives	1.64	1.87	2.58	3.66
Thiazole derivatives	.55	.53	.57	.96
N-Cyclohexyl - 2-benzothiazolesulfenamide	.66	.62	.92	1.19
2,2-Dithiobis (benzothiazole)	.50	.50	.54	.86
Other	.81	.78	.80	1.51
Antioxidants, antiozonants, & stabilizers	.69	.69	.69	1.18
Amino compounds	.64	.68	.70	1.18
Phenol,alkylated	.57	.51	.50	.74
Retarder: N-Nitro sodiphenylamine	.57	N/A	.63	.97
Acyclic Chemicals				
Dithiocarbamic acid derivatives	.97	.62	.78	1.35
Dimethydithiocarbamic acid, zinc salt	.76	.47	.46	.91
Bis (dimethylthio carbamoyl) disulfide	.92	.42	.36	.78

N/A - not available

Source: U.S. International Trade Commission, Synthetic Organic Chemicals (Washington, D.C.: Government Printing Office, various years).

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CATALYSTS

CATALYSTS

DESCRIPTION

A catalyst is a chemical which promotes a chemical reaction without being consumed by the reaction, i.e., after the reaction is over the catalyst is once again available to promote another reaction. Although some chemicals have been made using catalysts since the nineteenth century, the prominence of catalytic processes in the chemical industry is a twentieth century phenomenon. The Haber-Bosch process for producing ammonia, developed before World War I was one of the first important triumphs in the study of "catalysis", and the introduction of catalytic cracking into the petroleum industry in 1937 provided another boost to the use of catalysts.

Many commodity chemicals that have a wide range of uses are also used as catalysts: sulfuric acid, phosphoric acid, hydrofluoric acid, and caustic soda are prominent examples. More commonly, however, the term "catalysts" refers to chemicals that have catalytic properties as their most important attrbute. Many catalysts contain precious metals such as cobalt, nickel, molybdenum. vanadium, platinum, aluminum, palladium, and copper.

USES

In 1978 about 35 percent of the value of all catalyst shipments was used in petroleum refining (see Table 1). Of this 35 percent, 39 to 40 percent was used in catalytic cracking, 35 percent in alkylation, 11 to 13 percent in hydroheating, 7 to 8 percent in catalytic reforming, and 5 percent in hydrocracking. These processes are summarized below:

1) Catalytic cracking: heavier crude oil fractions are broken apart to make lighter fractions, the most important being gasoline.
2) Alkylation: light hydrocarbons are combined to form gasoline.
3) Hydroheating: sulfur, oxygen, and nitrogen in the petroleum feed stock are hydrogenated, and olefins and aromatics are saturated.
4) Catalytic reforming: naphthenes and straight-chain hydrocarbons are converted into the aromatics and into branched-chain hydrocarbons used in high-octane gasoline.
5) Hydrocracking: larger moledules are "cracked" into smaller molecules, and impurities are hydrogenated.

Catalytic converters in automobiles accounted for slightly less than 25 percent of the dollar value of all catalyst uses in 1978. In terms of production volume, catalyst use in catalytic converters is far less than in petroleum refining, but the greater use of precious metals (platinum and palladium) in converters accounts for the high value. That high dollar value may not be indicative of the ultimate market for catalytic converters, however, since in theory the metal can be recovered and reused (although it isn't clear how this would be accomplished in practice). If the precious metals could be successfully recovered, this would substantially reduce the value of the automotive catalyst market in future years.

TABLE 1

USE OF CATALYSTS IN PETROLEUM REFINING, 1978

Operation	Amount (million $)	Percentage of Total
Catalytic Cracking	144.3	39.2 - 40.1
Hydrotreating	40.0 - 48.0	10.9 - 13.3
Catalytic Reforming	27.4	7.4 - 7.6
Hydrocracking	19.5	5.3 - 5.4
Alkylation	128.8	35.0 - 35.8
Total:	360 - 368	

Source: Catalysts I: A $600 Million Market In Cars and Refineries," Chemical Week, March 28, 1979, p. 50.

In 1978 the use of catalysts in the rest of the chemical industry amounted to about $400 million, or 40 percent of the total use of catalysts. More than 75 percent of that $400 million was used in six important chemical operations (see Table 2). Polymerization catalysts were the biggest market, taking more than 25 percent of total chemical industry use of catalysts. Organic synthesis, a broad category which includes the production of such products as pigments, agricultural chemicals, pharmaceuticals, rubber processing additives, and a wide range of other chemicals, accounted for about 5 percent less. Oxidation catalysis used in making products such as ethylene oxide, nitric acide, sulfur trioxide, phthalic anhydride, and maleic anhydride, used about 11 to 12 percent of chemical industry catalysts. About 13 percent of chemical catalysts were used in hydrogenaton to make butadiene, styrene, and other products. and about seven percent were used in the hydrogenation of edible and inedible oils and in the hydrogenation of a variety of other substances. Steam reforming of natural gas to produce hydrogen, ammonia. and methane used about 6 percent of all chemical catalysts.

Table 3 presents some of the changes that have taken place in the market for petroleum catalysts during the last two decades. The volumes of reforming, catalytic cracking, and alkylation catalysts have remained stable (though substantial price increases have driven the value of catalysts in the latter two categories upward). Hydrotreating and hydrocracking have shown the largest gains in volume. The use of automotive catalysts is entirely a result of the environmental legislation of the 1970s. As noted earlier, the current value of automotive catalyst production may exaggerate the size of future markets if the precious metals can be economically recovered from the catalytic converters.

TABLE 2

USE OF CATALYSTS IN THE CHEMICAL INDUSTRY, 1963-1978

	1963		1972		1978	
	Value (million $)	Percent of Total	Value (million $)	Percent of Total	Value (million $)	Percent of Total
Steam reforming	3.8 - 4.5	4.0 - 5.3	10.4	5.8	23.0	5.8
Hydrogenation	5.5 - 6.0	5.8 - 7.1	12.3 - 13.3	6.8 - 7.4	23.5	5.9
Dehydrogenation	4.8 - 5.1	5.1 - 6.0	3.0 - 3.5	1.7 - 1.9	5.3	1.3
Oxidation	11.4 - 11.9	12.0 - 14.0	20.5 - 21.1	11.4 - 11.7	45.2 - 49.8	11.3 - 12.4
Organic synthesis	6.8 - 6.9	7.1 - 8.1	8.7	4.8	89.8	22.5
Polymerization	21.6 - 22.7	22.8 - 26.9	30.0 - 34.0	16.7 - 18.9	109.9-115.9	27.5 - 29.0
Other	27.9 - 41.1	32.8 - 43.3	90.0 - 95.1	50.0 - 52.8	97.7-103.3	23.2 - 25.8
TOTAL	85 - 95		180		400	

SOURCE: "CU Report: Catalysts," Chemical Week, August 24, 1963, 52-64; Donald P. Bruke, "Catalyst," Chemical Week, November 8, 1972, 33-45; Donald P. Burke, "Catalyst II: Chemicals Make It a $1 Billion a Year Market," Chemical Week, April 4, 1979, pp. 46-64.

TABLE 3

USE OF CATALYSTS IN PETROLEUM REFINING: 1963-1978

Operation	Value (millions of dollars) 1963	1972	1978	Volume (millions of pounds) 1963	1972	1978
Catalytic Cracking	45.6	68.8	144.3	305.0	274.0	286.0
Hydrotreating	3.5	10.4	40.0-48.0	4.1	10.0	20.0-24.0
Catalytic Reforming	20.1	30.3	27.4	4.7	5.0	5.0
Hydrocracking	NA	12.8	19.5		2.5	1.5-2.0
Alkylation	32.2	45.7	128.8	2,510.0	3,122.0	3,728.0
TOTAL:	101.4	168.0	360.0-368.0	2,823.8	3,413.5	4,040.5 4,045.0

Source: "Catalysts I: A $600 Million Market in Cars and Refineries," *Chemical Week*, March 28, 1979, p. 50.

Table 2 displays changes in sales of chemical catalysts over time. The largest increase was in organic synthesis, while the value of dehydrogenation catalysts increased very little. In most cases a substantial part of the increase in value was due to rising prices rather than increases in volume. One exception was steam reforming, in which the increase in the volume of catalysts used was particularly high. Dehydrogenation actually used fewer catalysts in 1978 than in 1963 because butadiene, whose production formerly consumed a substantial volume of catalysts, is now more frequently obtained more as a byproduct of ethylene synthesis.

With the exception of the case in which a chemical made by catalysis can also be made by another process, there are really no effective substitutes for catalysts. Technically, the reactions promoted by catalysts would all take place in their absence; however, they would take place too slowly to be economical.

RAW MATERIALS

The raw materials used in catalysts fall into several categories. Precious metals constitute an important component of many catalysts. Use of a number of important metals is shown in Table 4. The most interesting point to note is the rise in use of silver, cobalt, palladium and platinum. The increases in the latter two were brought about by the introduction of catalytic converters. In addition to the metals shown in Table 4, nickel is an important component of many catalysts. Compounds which contain copper, zinc, iron, chrome, and tin are also used as catalysts.

Other important materials used in catalysts are alumina (Al_2O_3), alumina-silica compounds, other silica compounds, clays, and diatomaceous earth (kieselguhr). These compounds are often used as supports for metals, and may also be employed as catalysts themselves. Originally, naturally occuring compounds were utilized, although now synthetic compounds are used as well. The most important synthetic compounds are the zeolites, which are synthetic alumina-silica compounds whose regular crystalline structures provide efficient catalytic action; these are used primarily in petroleum refining. Ceramics and powdered carbon are also used as supports for catalysts.

The raw materials for the commodity chemicals that find uses as catalysts (sulfuric acid, phosphoric acid, etc.) are discussed elsewhere.

PUBLIC DATA

The concentration ratios for product class 28198, Chemical Catalytic Preparations, are given in the *Census of Manufactures* (Table 5). As can be seen, according to the *Census of Manufactures*, concentration ratios seem to have been decreasing in recent years, particularly the four-firm ratio. However, this data must be viewed with caution for several reasons. First, 1976 concentration ratios constructed from production estimates supplied by the *Kline Guide to the Chemical Industry* show a four-firm concentration ratio of 55 percent and an eight-firm ratio of 80 percent. Although it is possible

Table 4

U.S. CONSUMPTION OF SELECTED METALS FOR CATALYSTS, 1969-1976

	1969	1976
Rare Earth[a]	10,584	12,040
Molybdenum[b]	1,514	1,843
Vanadium[b]	392	490
Cobalt[b]	286	1,446
Platinum[c], [d]	234	624
Palladium[c], [d]	216	329
Other platinum group[c], [d], [e]	37	28
Silver[c]	4,081	11,758
Mercury[f]	2,958	1,264

a/ Thousand pounds of oxide equivalents.
b/ Thousand pounds of continued element.
c/ Thousand troy ounces.
d/ Includes non-catalyst and catalyst used by the chemical and petroleum-refining industries and, in 1976, the automotive industry.
e/ Iridium, osmium, rhodium, ruthenium.
f/ Flasks, 76 pounds each.

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, 1972 and 1979).

TABLE 5

CONCENTRATION RATIOS FOR PRODUCT CLASS 28198 CHEMICAL CATALYTIC PREPARATIONS

	4 Firm	8 Firm	20 Firm	50 Firm
1972	38	63	93	100
1967	46	72	96	100
1963	50	70	97	100
1958	61	78	99	100

Source: U. S. Department of Commerce, Bureau of the Census, 1972 Census of Manufactures, (Washington, D. C.: Government Printing Office, 1975).

that the 15-year trend evidenced in the Census of Manufactures was reversed in four years, such a reversal seems unlikely. Second, both the Census of Manufactures and the Kline Guide exclude from their calculations captive consumption and commodity chemicals used as catalysts . But, these catalysts comprise a substantial percentage of catalyst production. A comparison of the production estimates for 1963 given in Tables 1 and 3 ($185-$195 million) with the figure for value of shipments from the 1963 Census of Manufactures ($75.2 million) suggests that captive production and commodity chemicals encompass the majority of production. although the Kline Guide suggests that in 1976 these categories were somewhat less than 40 percent of all catalyst production.

Another reason to question the validity of the concentration ratios provided by the Census of Manufactures is that "Chemical Catalytic Preparations" is not the relevant market; a catalyst that is used for catalytic cracking, for example, does not compete with a catalyst used for hydrogenation. The relevant markets are really much narrower segments of the chemical industry, in some cases corresponding to the segments discussed in the section on the uses of catalysts, and in other cases corresponding to subdivisions of those segments. Without going into great detail for each market, it is safe to say that, based on reports in trade journals, catalyst markets are highly concentrated. It is not unusual for one firm to account for more than half of the sales in a particular market, and for three firms to account for virtually all sales. Although the catalysts sold in any given market may change quite rapidly in a short period of time because of the development of new products, the same firms tend to remain dominant. Moreover, even though there is some entry into and exit from each market (a prominent example being the exit of American Cyanamid and Nalco from the catalytic cracking markets after the introduction of zeolites), the roster of firms in each market was relatively stable during the 1960s and 1970s.

No data on catalyst imports are available and nothing in the trade journals suggested that such imports are important. Thus, the United States appears to be one of the technological leaders in this area. As shown in Table 6, exports were somewhat more than 10 percent of the value of U.S. catalyst production during the 1970s.

TABLE 6

EXPORTS OF CATALYTIC COMPOUNDS

(millions of dollars)

Year	Catalysts, nickel compound	Catalysts, compounds other than nickel
1976	16.3	95.4
1975	13.7	78.6
1974	6.8	46.4
1973	6.6	52.8
1972	6.8	38.5
1971	10.0	41.8

Source: U.S. Department of Commerce,
Exports: Commodity by Country, FT 410, various years.

The large increase in the dollar value of catalyst production is due in part to increased catalyst usage, particularly through the creation of a large new market for catalytic converters. But much of the increase in sales is attributable to price increases. As can be seen by examining Tables 7 and 8, catalyst prices have greatly increased since 1963, especially during the 1970s. The precious metals used in catalysts have seen particularly sharp increases during the 1970s.

COMPANIES IN SEGMENT

The *Census of Manufactures* lists 37 companies with shipments of $100,000 or more. This estimate does not include firms that produce: catalysts for automobiles, commodity chemicals that have uses as catalysts, and catalysts that they use themselves. Excluding captive production and commodity chemicals, the *Kline Guide* estimates that there are 20 producers of catalytic preparations. *Chemical Week* lists 24 firms which produced catalysts in 1972, and 23 in 1979.

It is difficult to determine the profitability of catalyst production because catalysts are a very small part of the sales of most of the leading catalyst producers. The exceptions are closely held concerns, whose financial data are not available. Table 9 gives estimated sales, not including commodity chemicals and captive production, for the major U.S. catalyst producers. Of these firms, Filtrol had by far the greatest ratio of catalyst sales to total sales in 1970, slightly more than 30 percent. All of the other firms could only attribute well under 10 percent of their sales to catalysts.

TABLE 7

PETROLEUM CATALYST PRICES

(dollars per pound)

Operation	Year 1963	 1972	 1978
Fluid bed catalytic cracking	.15	.24	.50
Moving bed catalytic cracking	.12	.30	.55
Hydrotreating	.85	1.04	2.00
Reforming	4.28	6.06	5.48
Hydrocracking	--	5.12	9.75-13.00

Source: "Catalysts I: A $600 Million Market in Cars and Refineries," Chemical Week, March 28, 1979, p. 50.

TABLE 8

CHEMICAL CATALYST PRICES

(dollars per pound)

Operation	Catalyst	Year 1963	 1972	 1979
Hydrogenation	Nickel (25% in oil)	.77	.75-.87	2.05-2.16
Dehydrogenation	Chrome-alumina	.67	1.00	2.00
	Promoted iron oxide	.38	.48	1.40
Organic synthesis	Aluminum chloride	.12	.15	.36

Sources: "Catalysts," Chemical Week, August 24, 1963, pp. 52-64;"Catalysts," Chemical Week, November 8, 1977, pp. 35-45; and "Chemicals Make it a $1 Billion a Year Market," Chemical Week, April 4, 1979, pp. 46-63.

TABLE 9

ESTIMATED SALES, MAJOR U.S. PRODUCER OF CATALYSTS: 1976

Company[a]	Sales (millions of dollars)
Engelhard Minerals & Chemicals	85
American Cyanamid	70
W. R. Grace (Davison Division)	60
Air Products and Chemicals (Houdry Divsion)	50
UOP	45
Matthey Bishop	30
Filtrol	25
Kewanee Industries (Harshaw Division)	20
Union Carbide	20
Girdler	15
Nalco[b]	15

[a] Ownership is given as of 1976. Since then, UOP has become part of The Signal Cos., Inc., Filtrol has become part of U.S. Filter, Kewanee Industries has become part of Gulf Oil, and Girdler has become part of United Catalysts, Inc.

[b] Incudes $10 million in sales of Katalco, jointly owned by Nalco and ICI.

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry, (3rd ed., Fairfield. NJ: Charles Kline & Co., 1977).

INNOVATION

It appears that Catalyst producers are some of the most secretive in the chemical industry. The catalysts themselves represent only a small fraction of the cost of producing the final product, but a small improvement in the catalyst can bring about a significant decrease in costs of production. For example, one new catalytic cracking catalyst was estimated to reduce the cost of a gallon of gasoline by 1/3¢ per gallon. Extrapolating this to all catalytic cracking capacity leads to a savings of more than $250 million per year, about 60 percent of the value of the entire petroleum catalyst market. Because of the secrecy surrounding catalysts, details about the introduction of new catalysts are sketchy, although it is apparent from the trade literature that innovation is high. It seems that refiners are often reluctant to experiment with new catalysts for fear of the economic consequences of failure (e.g., a cost increase of 1/3¢ per gallon) but once the value of a new catalyst is demonstrated, refiners quickly adopt the new product. For example, zeolites, introduced in 1962, accounted for 90 percent of all catalysts used in catalytic cracking in 1972.

OTHER CHEMICAL PRODUCTS

Other Chemical Products Segment Summary

Cellulosic Man-made Fibers

Polishes and Sanitary Goods

Paints and Allied Products

Adhesives and Sealants

Explosives

Printing Ink

Carbon Black

Gelatin

Salts, Essential Oils, and Chemical Preparations. NEC

Other Chemical Products includes those portions of the industry that are not classified elsewhere due to the presence of chemicals which either belong to more than one other segment or have unique characteristics barring them from any of the other segments. Most of the components are not very innovative, though some develop new formulations based on new chemicals developed in other industries. For example, a new surfactant may be used for new formulations in the polishes and sanitary goods industry. Two industries, adhesives/sealants and printing ink, do exhibit a large amount of innovation.

Adhesives are bonding agents that hold similar or dissimilar substrata together. The closely related sealants are used to fill gaps or joints, and may also function as waterproofing agents. In the last ten years a number of important products in this area have come under suspicion because of safety and health concerns. One of the intermediates used in making almost all epoxy adhesives is a suspected carcinogen, and workplace emissions of this intermediate have been regulated by OSHA. Formaldehyde emissions from the urea formaldehyde adhesives used in construction have also come under government scrutiny. Concern about the carcinogenity of materials and the high levels of energy needed to produce many existing adhesives have prompted a search for new products, and a number of new products have been recently introduced.

The adhesives and sealants industry appears to be very unconcentrated. In 1977 there were 750 manufacturers, with the top 50 accounting for 68 percent of industry sales. The large companies usually have a wide product line, while the smaller companies specialize in specific product or market areas.

We believe that the printing ink industry has long had a very low degree of innovation. but that recently a new process and new products have been developed. Previously, inks dried on paper through the evaporation of a solvent. But now ink is being "cured" with infrared heat. Unlike most firms in the industry, the firms developing the new technology and products are not simply blending existing ingredients--they are developing new products.

E-275

Cellulosic Man-Made Fibers

CELLULOSIC MAN-MADE FIBERS

DESCRIPTION

There are two types of cellulosic man-made fibers: rayon and cellulose acetate. These fibers are used primarily for apparel and home furnishing fabrics. Other uses include material for cigarette fibers, fillings for pillows, and strengthening material for hoses, tires, and industrial belts. The major end uses of cellulosics are summarized in Table 1. As indicated by the table, rayon and acetate are substitutes for many natural and synthetic fibers.

The manufacture of these fibers is influenced by two major factors: the cost of raw materials, and the demand for cellulosic fiber commodities. Although the cellulosics industry is substantial, with total product shipments for 1977 valued at $853 million,[1] it comprises only a small portion of all textile manufacturing (See Figure 1). Since the vast majority of cellulosic man-made fibers are used for common fabrics, it is clear that these fibers are highly substitutable.

HISTORY

Intended originally as a low cost replacement of silk, rayon was the first man-made fiber. Commercial manufacturing began in France in the late 1800s and was soon followed by production in Germany, Switzerland and Belgium. England also joined in and introduced the "viscose process", allowing for cheaper production. By 1912 rayon hosiery was being produced in quantity and four years later knitted rayon fabric for outerwear became available. World War I inspired still more production and several new plants were built shortly thereafter. As a result of technical advances in the production process, rayon became entrenched in the American fabric industry.

British Celanese Limited (now Celanese Corporation) made the first feasible acetate fiber in 1920, and in 1924 began the first United States acetate production in Cumberland, Maryland. In 1954 Celanese developed an economical process for the production of triacetate and commercialized it under the trade name "Arnel". Although acetate and rayon demand decreased during the mid-1950s, it was revitalized in the early 1960s with the introduction of textured acetate doubleknit fabrics and solution-dyed acetate. Demand for acetate also increased for its use as tow in cigarette filters. Cellulose acetate successfully infiltrated the textile industry, as had rayon.

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[1] U. S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D. C.: Government Printing Office, 1979).

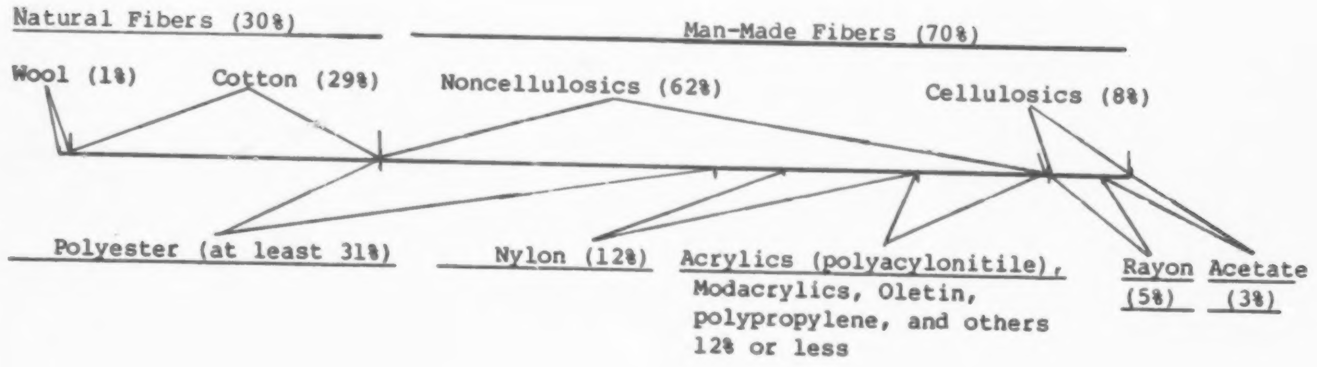
TABLE 1
MAJOR END USES OF CELLULOSIC MAN-MADE FIBERS

Rayon				Cellulose Acetate			
Apparel	Home Furnishings	Industrial Products	Other	Apparel	Home Furnishings	Industrial Products	Other
Women's and Children's Apparel	Draperies	Automobile tires	Household Products	Women's and Children's Apparel	Carpets	Automobile Upholstery	Tow for cigarette filters (large volume)
Lingerie	Slip covers				Rugs		
Dresses	Upholstery	Hoses	Tapes	Pantsuits	Curtains		
Suits	Table cloths	V-belts	Ribbons	Lingerie	Draperies		
Blouses	Bed spreads	Conveyor belts	Cleaning Cloths	Knitted Jerseys	Fillings for pillows		
Sportswear	Blankets			Uniforms			
Coats	Carpets		Baby diapers	Sportswear, blouses			
Rainwear	Mattress Covers		Sleeping bag liners	Dresses			
Accessories	Sheets			Evening Gowns			
Milinery	Wall coverings						
Underwear			Hospital Goods	Men's and Boy's Wear			
			Scrub suits				
Men's and Boy's Wear			Dividers				
Sport shirts			Drapes	Uniforms			
Summer and year-round suits							
Slacks							
Rugged outwear							
Jackets			Other:				
Raincoats			Casket linings				
Work clothes			Book-bindings				
Ties			Filters				
Uniforms							

Sources: American Fabrics Magazine, Encyclopedia of Textiles (2nd ed., Englewood Cliffs, NJ: Prentice-Hall, Inc., 1973); and Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

FIGURE 1

BREAKDOWN OF TEXTILE PRODUCTS BY QUANTITY



Source: U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978).

PRODUCTION PROCESSES

Viscose and cuprammonium processes, from which most rayon is currently made, consist of the following major steps: sheets of bleached cellulose sulfate pulp are steeped into a solution of caustic soda; the alkali cellulose sheets that result are crumbled, stored for aging, combined with carbon disulfide, and again dissolved in caustic soda, yielding a viscous solution called viscose, which is passed through a dilute solution of sulfuric acid and extruded through the holes of a spinneret. Fine filaments are formed which are spun into yarn or cut into staple. The cuprammonium process is similar, except ammonium copper oxide is used, and the filaments are stretched to yield the finest (thinnest) filaments to be manufactured commercially.

In the production of cellulose acetate, cellulose is combined with acetic acid in a process called acetylation. Hydrolysis and precipitation reactions yield solid cellulose acetate which is then washed, dried, and liquefied with acetone. As with rayon production, filaments are formed by streaming the solution through a spinneret.

Cellulose production presents certain health risks from the exposure to toxic reagents. The final products are non-toxic, however.

ECONOMIC OUTLOOK

Producers

Standard and Poors (1978) reported only 22 manufacturers of cellulosic man-made fibers. The 1977 Census of Manufactures, however, stated that the total number of establishments for the industry was 10. To add to the confusion, the Kline Guide to the Chemical Industry (1977) listed seven major cellulosics producers. These companies are listed in Table 2.

TABLE 2
CAPACITIES OF MAJOR U. S. PRODUCERS OF CELLULOSIC MAN-MADE FIBERS
(millions of pounds per year)

Company	Acetate Capacity[a]	Rayon Capacity[b]
Akzona	--	110
AvTex	45	455
Beaunit	--	75
Celanese	373	--
Courtaulds	--	185
DuPont	50	--
Eastman Kodak	265	--
Total	733	825

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[a] 1976 data

[b] 1975 data

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

These discrepancies are most likely due to differences in the classification of the businesses and establishments associated with the industry. Yet, regardless of such differences, it appears that the industry is concentrated. Furthermore, Table 2 shows that Celanese possesses 51 percent of the production capacity for acetate fibers and that Avtex possesses 55 percent for rayon fibers.

Production

Table 3 presents the production output of man-made fibers. These data reveal large drops in production for most categories during the 1974 to 1975 period. This was largely due to rising energy costs and a general economic recession.

Sales vs. Costs

Data presented in the 1977 Census of Manufactures indicate that from 1972 to 1977 the annual percentage increase (in constant 1972 dollars) of the cost of raw materials for the cellulosics industry was 8.65 percent. Nevertheless, the annual percentage increase (constant 1972 dollars) from 1972 to 1977 in the price of cellulosics was 0.27 percent.[2/]

The sales volumes for 1972 and 1977 (in constant 1972 dollars) also indicate that the industry's real growth is stagnant. Furthermore, the number of firms competing in the industry has been reduced during this period as several marginally profitable firms, faced with the aforementioned marginal squeeze, left the industry (See Table 4). The major reason for the marginal squeeze has been competition from other synthetics. The drastic price advantage of these synthetics (illustrated in Table 4-5) has contributed heavily to sales stagnation and industry consolidation.

The differences between the Kline Guide and the Producer Price Index are primarily due to differences in the way these data were collected. The PPI data reflect the manufacturer's list prices for items, while the Kline Guide data attempt to reflect actual market prices.

An aspect of the industry that has improved over the last few years is foreign trade. Table 4 shows the compound average annual growth rates from 1967 to 1976 for the real value of cellulosic exports and imports. Although the foreign market appears to be continually improving, Table 6 also shows that this market is only 8.7 percent of all industry shipments.

[2/] GNP price deflator from: Executive Office of the U.S., Economic Report of the President (Washington, D.C.: Government Printing Office, 1979).

TABLE 3

PRODUCTION OUTPUT OF MAN-MADE FIBERS

Product	Year											Per Annum Annual Change (percent)	
	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1977-78	1968-78
CELLULOSIC FIBERS													
Acetate[a]	308	290	298	313	382	462	429	476	498	498	490	6	-5
Rayon	597	598	543	436	817	895	965	915	875	1078	1104	0	-6
SELECTED NONCELLULOSIC FIBERS													
Acrylic[b]	726	709	621	525	631	742	626	545	492	533	521	2	3
Nylon[c]	2550	2326	2075	1857	2124	2175	1974	1595	1355	1411	1350	10	7
Polyester[d]	3800	3642	3340	2995	2926	2888	2328	1142	1022	939	827	4	18

[a] includes diacetate and triacetate; excludes production for cigarette filtration.
[b] includes modacylic.
[c] includes aramid.
[d] excludes yarn and monofilaments.

Source: Chemical and Engineering News, June 11, 1979.

TABLE 4

ECONOMIC INDICATORS: 1967 - 77

Variable	Year		
	1967	1972	1977
Total Number of Establishments	23	18	10
Value of Product Shipments (1972 constant dollars, in millions)		684.6	602.1

Sources: Executive Office of the U.S., Economic Report of the President (Washington, D.C.: Government Printing Office, 1979); and U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

TABLE 5

INDICES OF AVERAGE PRODUCER PRICES OF MAN-MADE FIBERS

Year	Source			
	Kline Guide to the Chemical Industry[a]		Producer Price Index[b]	
	Synthetic	Cellulosic	Synthetic	Cellulosic
1967	100.0	100.0	100.0	100.0
1968	92.5	96.1	98.8	100.4
1969	86.2	98.0	98.7	100.9
1970	82.1	98.6	98.5	100.9
1971	78.3	99.6	98.0	102.4
1972	65.6	99.8	98.0	106.2
1973	74.6	111.6	97.9	109.0
1974	74.0	152.5	100.8	129.2
1975	81.9	218.8	101.5	145.8
1976	-	-	102.2	-
1977	-	-	106.5	-
1978	-	-	107.6	-
1979	-	-	117.8	-

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[a] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

[b] U.S. Department of Commerce, Producer Price Index, various years.

The major factor leading to the apparent downturn and consolidation of the cellulosics industry seems to be the inability of manufacturers to underprice the other synthetic fiber competition. The recent large increases in petroleum costs seem to have made cellulosic production too expensive to sucessfully compete with the less expensive but equally substitutable synthetics. Because raw material costs constitute a large fraction of total production costs, it is very difficult for manufacturers to produce cellulosic fibers that can be sold at cheaper prices. However, if production or raw material costs increase substantially for the noncellulosic man-made fibers, then cellulosics could experience a comeback, although it would be a very slow one. It appears unlikely, given the fixed nature of manufacturing processes and the emphasis on reducing processing costs, that man-made cellulosics will be affected by TSCA.

TABLE 6

VOLUME AND GROWTH OF FOREIGN TRADE OF CELLULOSICS: 1967-1976

Factors	Averages
Exports as a percent of industry shipments	8.7
Imports as a percent of apparent consumption	7.9
Compound average annual rate of growth 1967-76 (percent):	
Value of shipments (current $)	0.5
Value of exports (current $)	12.3
Value of imports (current $)	7.4

Source: U.S. Department of Commerce, *1978 U.S. Industrial Outlook* (Washington, D.C.: Government Printing Office, 1978).

E-285

Polishes and Sanitary Goods

POLISHES AND SANITARY GOODS

DESCRIPTION

This section gives a general description of SIC 2842 and its relation to other industrial segments. A later section discusses industry structure and production.

This SIC includes a diverse set of products, producers, and markets and cannot be classified as a homogeneous segment. The "industry" includes producers of polishes; waxes; deodorants; household, institutional, and industrial disinfectants ; dry cleaning solutions; household bleaches; and other sanitation preparations.

Shipments were valued at $2,610 million in 1977[1] and were distributed to a wide range of users. Bureau of the Census data indicates there were 1015 establishments in this SIC in 1977, with 780 (76.8 percent) having less than 20 employees. Census data also indicate that there were 1108 establishments in 1972.

The use of industrial cleaning products extends to almost every other segment of the economy. Table 1 shows sales only to major market segments, some of which are for further resale.

PRODUCTION

The elements for the formulation of cleaning and polishing products for a wide variety of uses come from a relatively limited group of chemicals. The following list of products shows their chemical sources and some general uses:

- Bleaches--sodium hypochlorite or calcium hypochlorite, used in laundries.
- Alkaline Cleaning Compounds--mixtures of inorganic alkalies such as hydroxides, carbonates, silicates, often with soaps, detergents or bleaches. Their major uses are in metal cleaning, dishwashing, paint-stripping and laundry alkalies.
- Scouring Cleaners--basically inorganic abrasives like pumice, silica, felspar or volcanic ash, often containing detergents, bleach or phosphates.
- Synthetic Detergents--usually organic surfactants, the active ingredient in laundry detergents, and used as a mixer in many products. (The surfactants are described in a separate chemical profile and will not be discussed here.)

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[1] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

- Hand Soaps--based on synthetic detergents or natural products using tallow, used in lavatories.
- Acid Cleaners--mixtures of inorganic acids and bisulfates, often with a minor amount of synthetic detergents. They are used in metal cleaning and dairy processing.
- Deodorants--a mixture of perfume oils, occasionally with a disinfectant, either for aerosol or natural diffusion application.
- Disinfectants--various fungicides, bactericides and mildewcides, used in combination with surfactants and deodorants.
- Waxes--natural vegetable or synthetic polyolefin substances, used on furniture, floors, leather, and exterior finishes.

TABLE 1

SALES OF CLEANING AND POLISHING PRODUCTS BY USER MARKETS: 1977

Market Segment	Percent of Total
Retail stores	12.8
Commercial laundries and dry cleaners	11.1
Contract cleaners	9.2
Industrial and office buildings	9.2
Public food service	9.2
Hospitals and nursing homes	8.9
Food processors and farms	8.9
Transportation services	8.2
Schools and colleges	4.9
Metal processors	4.9
Hotels and motels	4.6
Government	4.6
Other	3.5
Total	100.0%

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 137.

Industry Structure

As previously suggested, the industry is highly diffuse with less than 30 companies operating on a national basis. There are no publicly available data that comprehensively list all of the producers or even major suppliers, since there are broadly divergent market groups and more than 1,000 manufacturers.

One large market group, industrial and institutional cleaning compounds (which includes acid cleaners, deodorants, disinfectants, bleaches and synthetic detergents), is relatively concentrated; the top 10 producers had about 44 percent of total sales in 1976. Table 2 lists these producers and their 1976 sales volumes.

TABLE 2

SALES VOLUMES MAJOR U.S. PRODUCERS OF INDUSTRIAL AND INSTITUTIONAL CLEANING COMPOUNDS, 1976

Rank	Company	Sales Volume (millions of dollars)
1	Economics Laboratory	135
2	S. C. Johnson	110
3	Chemed	80
4	National Chemsearch	65
5	National Service Industries	60
6	West Chemical Products	50
7	BASF Wyandotte	45
8	Procter & Gamble	45
9	Diversey	40
10	Purex	35
Total Sales of all Producers in the Industry: 1976		1,525

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1976), p. 138.

Although this market segment can be broadly categorized by type of product, final products in retail markets are diverse. Many of the larger firms have their manufacturing and sales organized along product lines. For example, Economics Laboratory is divided into four divisions: Institutional (food service and janitorial), Klenzade (dairy farms, food processors), Magnus (metal finishing and transporation) and Magnus Maritec (marine).2/

The major categories of substantial raw materials used by this industriy are indicated in Table 3.

2/Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 138.

In addition to chemical synthesis, the production of polishes and sanitary goods requires a great deal of mechanical mixing. However, PMN submission requirements only affect new processes of chemical synthesis. Therefore, only firms that formulate and/or synthesize the ingredients would be affected. This involves a minority of firms, as most merely purchase and mix ready-made components. In fact, with respect to polishes and sanitation goods, BASF Wyandotte and Proctor & Gamble are probably the only major firms that would be directly affected by TSCA.

Many materials are unlikely to undergo changes in chemical synthesis because their composition and application are relatively simple. As an example, it is unlikely that the chemical formula for bleach could be changed and still have it retain its oxidation power, the source of its effectiveness. (Stronger oxidizing agents such as perchlorates are much more expensive and do not compete commercially on a large scale with the common household and industrial bleaching agents.) Furthermore, it appears extremely unlikely, for chemical and processing reasons, that a less expensive but equally strong bleaching agent would be substituted. Of the materials associated with the industry, surfactants, because of their diversity and innovativeness, would primarily be involved in chemical changes. (See Chemical Profile on Surfactants.).

TABLE 3

MAJOR GROUPS OF RAW MATERIALS USED IN POLISHES AND SANITARY GOODS PRODUCTION, 1977

Item	Sales Volume (millions of dollars)
Surfactants and wetting agents	80.3
Perfumes	24.2
Builders	10.7
Sodium Silicates	.8
Labels, containers	344.6
Oils & Greases	5.0
Caustics	36.0
Other, not classified	690.0
Total	1,181.7

Source: Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

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Paints and Allied Products

PAINTS AND ALLIED PRODUCTS

DESCRIPTION

Paints and allied products are categorized into two types: trade sales paints and industrial finishes. Trade sales paints are often sold in retail markets and are used as coatings for buildings, ships, etc. Industrial finishes are made to user specifications are are sold to manufacturers for use on automobiles, appliances, furniture, and other items. From 1966 to 1976 the industry experienced relatively slow and steady growth, as indicated in Table 1. Between 1973 and 1976 inclusive, production gains slowed due to the general recession in 1974 and 1975. Thus, the large gains in sales from 1973 to 1976 were primarily due to price increases.

Paint technology remained static for many years prior to World War I, consisting basically of mixing a limited number of vegetable oils with solvents, minerals, and some synthetic dyes. After the war, many new synthetic raw materials and additives were developed, producing a wide variety of consumer and industrial coatings.

The paint segment is relatively more mature than most of the other chemical segments but is also relatively small in terms of revenue. Its small size is illustrated in Table 2. which compares the sales of paints with several other representative segments.

Although paints are often categorized by market, the chemistry of coatings is largely determined by the product specification desired and, thus, by the components within the paint necessary to obtain the desired characteristics. All paints are composed of at least two and usually three major components: (1) the film-forming binder, consisting of resins or oils, (2) the dispersion medium, which maintains fluidity (usually water or an organic solvent) and (3) a pigment system, to impart color and opacity. The first two components are sometimes called the vehicle. When applied, the solvent evaporates, leaving the binder and pigment.

Because coatings are designed with different substrates, application techniques, curing methods, costs, durabilities, and a host of other specifications, the variety and specialization of finished products are among the highest in any of the chemical industries.1/ These many varieties and specializations result from various combinations of the aforementioned components.

1/Joan Huber, ed., Kline Guide to the Paint Industry, (5th ed., Fairfield, NJ: Charles Kline & Co., 1978), p. 28.

TABLE 1

U. S. PRODUCTION AND SHIPMENTS OF TRADE SALES PAINTS AND INDUSTRIAL FINISHES, 1966-1976

	Production (million of gallons)			Shipments millions of dollars		
Year	Trade Sales Paints	Industrial Finishes	Total	Trade Sales Paints	Industrial Finishes	Total
1966	415.9	421.1	837.0	$1,312.4	$1,051.9	$2,364.4
1967	398.4	383.1	78.5	1,329.5	1,018.7	2,348.3
1968	423.7	419.5	843.2	1,427.5	1,159.3	2,586.8
1969	430.3	450.1	880.4	1,473.5	1,303.5	2,776.7
1970	427.6	399.2	826.8	1,497.6	1,239.4	2.737.1
1971	431.1	443.5	874.4	1,562.8	1,268.2	2,830.9
1972	451.5	475.3	926.9	1,659.3	1,349.8	3,009.2
1973	424.0	473.0	897.0	1,658.9	1,473.9	3,133.1
1974	474.6	457.3	932.0	1,870.9	1,800.7	3,671.6
1975	451.5	438.1	889.6	2,079.0	1,947.6	4,026.6
1976	473.5	455.2	928.7	2,446.2	2,231.9	4,686.0
		Average Annual Growth (in percent)				
1966-1971	0.7	1.0	0.9	3.6	3.8	3.7
1971-1976	1.9	0.5	1.2	9.4	11.9	10.6

Source: U. S. Department of Commerce, Bureau of the Census, Current Industrial Reports (Washington, D. C.: Government Printing Office, various years).

TABLE 2

SALES COMPARISON OF THE PAINT INDUSTRY WITH OTHER CHEMICAL SEGMENTS, 1977

Segments	Revenue in Millions
Paints	5,100
Basic organics	21,755
Inorganics	10,350
Agricultural Chemicals	9,685
Plastics	11,615

Source: Mary K. Meegan, Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

RAW MATERIALS, CLASSIFICATION

Natural Oils and Resins

Natural oils and resins account for approximately 20 percent of all binders used. They include oils such as linseed, soybean, tall, tung, fish (menhaden), castor, coconut, and safflower. The only natural resin, shellac, has been largely replaced by synthetics. Natural oils, once the only drying oils available for coatings, are used singly or in combination with other natural or synthetic binders. Their use has declined from 624 million pounds in 1965 to 419 million pounds in 1972, and is expected to continue to decline.[2]

Natural oils are slower drying and less durable than synthetics. Their primary advantage is that they are less expensive and non-toxic, and their properties are well known. Linseed oil is the largest selling natural oil, comprising 35 percent by volume of all natural oils used in 1977. It has excellent exterior durability, and is relatively fast-drying.[3] Fish, castor, coconut, tall, and soybean are semi-drying oils, and are used in combination with other binders. Their main advantage is lower price.

Synthetic Resins

Synthetics were first used in 1923 when cellulosic nitrate was introduced to lacquer. Since then, their growth has been at the expense of natural oils. The major categories, in order of their volume of use, are alkyds, acrylics, vinyls, epoxies, aminos, urethanes, cellulosics, styrenes, and phenolics.[4] These resins are used singly or in combination, and new mixtures are constantly being devised.

Alkyds are relatively low in cost, have a high degree of compatibility with other resins, and are often used in combination with other synthetics and natural oils. They are the products of saturated polycarboxylic acids and polyfunctional alcohols modified by fatty acids. They are used in interior and exterior enamels and coatings, but are hardly used in water-based coatings. Alkyds lost some price competitiveness during 1974 and, as a result, lost some of their market share.[5] Research is currently being conducted to develop water-based alkyds.

Acrylics are predominantly copolymers of esters and polymers of acrylic or methacrylic acid. Because a number of esters can be copolymerized together, there are many varieties of resins available. Acrylics are used extensively in exterior and interior high-gloss and semi-gloss coatings, as well as in automobile finishes. Acrylics are used both in solvent and latex-based coatings.

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[2] *Ibid.*, p. 31.

[3] *Ibid.*, p. 32.

[4] *Ibid.*, p. 29.

[5] *Ibid.*

Vinyl resins are formed from the polymers and copolymers of vinyl acetate and vinyl cloride by copolymerizing with fumarates, maleates, acrylates, and methacrylates. Vinyls are used primarily in interior latex paints, since they are less expensive than acrylics and more durable than styrenes.

Epoxy resins are made by the reaction of bisphenol with epichlorohydrin, followed by cross-linking with hardeners. They are experiencing increases in a wide variety of applications due to their excellent adhesion, chemical resistance, and overall durability. They are used in solvent, aquatic, and powder coatings. The interest in developing a replacement for solvent-based coatings will result in powder coatings doubling their market share by 1982, according to the American Paint and Coatings Journal.[6]

Amino resins are urea-formaldehyde and melamine formaldehyde, and are always used in combination with other binders. They have excellent color and gloss retention, and are used in high-gloss baking finishes.[7]

Urethane resins, a newer form of binders, are formed by reacting isocyanates with hydroxyl compounds. They have excellent durability, corrosion resistance and adhesion. They are more costly than acrylics, and are being used in automotive finishes.[8]

The remaining binders, cellulosics, styrenes and phenolics, are older products whose growth has been slowed by replacement from the newer synthetics. They are lower in cost, but their price advantage is not enough to offset their eventual decline.[9]

Pigments used in paints are described in detail in the profile "Inorganic Pigments", and no discussion of their chemistry is made here.

Solvents are used in large quantities in all paints to add fluid properties and to affect drying time, flow characteristics, and consistency of application. The most widely used solvents are water, ketones, esters, alcohols, mineral spirits, toluene, xylene, naptha, and glycols. Data on their use is incomplete. The solvent used depends on its ability to dissolve the binder and mix with the pigment, along with its cost. Solvents do not react chemically with the binder and pigment other than to dissolve the binder, so the choice of solvent until the late 1960s was based solely on dissolving properties, volatility, and price.

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[6] American Paint and Coatings Journal, June 16, 1979.

[7] Meegan, Kline Guide, p. 31.

[8] Ibid.

[9] Ibid.

The advent of federal and state air quality regulations has had a great impact on the choice of solvents now in use. While petroleum solvent-based paints presently enjoy a 60 to 70 percent market share of industrial coatings, they are steadily losing market share to water-based coatings, powders, and high solids.[10] Research and development efforts are examining more efficient processes of applying and curing finishes without the use of petroleum solvents. These processes include powder coating, electrodeposition, and thermal and radiation curing.[11] It is projected that, by the mid-1980s, regular solvent-based paints will have only 25 percent of the market.[12]

The paint industry is one of the few remaining chemical segments characterized by many small firms. Table 3 shows the trends in the number of producers in 1963, 1967, 1972, and 1977. The total number of producers has been getting smaller, mainly due to mergers and acquisitions.[13] Because the products are relatively heavy per unit of value they are not shipped long distances. There high shipping costs have created a barrier to effective nationwide distribution by large firms. Thus, smaller manufacturers are very competitive on a regional basis.[14]

RAW MATERIALS, PRODUCTION AND SALES

As has most other segments of the chemical industry, the paint industry has had large increases in the costs of raw materials since 1973. Table 4 illustrates this trend for several major raw materials . Producers of trade sales paints face a mature competitive market, where price reductions to gain and maintain market share commonly occur. Thus, margins on sales have been reduced significantly during the 1970s.

Table 5 illustrates the reduction in average profit margins on paints as compared to all manufacturing industries' average margin on sales.

Trade sales have suffered more than industrial finishes, because industrial coatings are more specialized and can command higher margins. Table 6 compares the price indices of trade sales and industrial finishes for 1967 through 1977.

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[10] Ibid., p. 35.

[11] U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978), p. 120.

[12] C. H. Kline & Co. estimate.

[13] U.S. Department of Commerce, 1978 U.S. Industrial Outlook, p. 120.

[14] U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975); and U.S. Department of Commerce, Bureau of Census, Current Industrial Reports (Washington, D.C.: Government Printing Office).

TABLE 3

PRODUCERS AND CONCENTRATION IN THE PAINT INDUSTRY, FOUR SELECTED YEARS

Year	Number of Producers	Top Eight Producers' Share of Market (in percent)
1963	1,579	--
1967	1,459	--
1972	1,317	33
1977	1,275	44

Sources: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977); U.S. Department of Commerce, 1978 U.S. Industrial Outlook (Washington, D.C.: Government Printing Office, 1978); and U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures and 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1975 and 1979).

TABLE 4

PRICE INDICES OF SELECTED PAINT RAW MATERIALS, 1973-1978

1967 = 100

	1973	1974	1975	1976	1977	1978
Paint resins	--	--	--	106.9	112.4	112.4
Linseed oil	110.9	343.7	318.5	206.3	197.0	155.3
Nitrocellulose	115.2	137.8	175.7	186.9	198.5	206.3
Epoxy, unmodified	--	--	--	100.0	106.4	110.8
Toluene diisocyanate	--	--	--	112.1	120.6	113.6
Paint pigments	--	--	--	102.7	104.4	105.2
Calcium carbonate	122.2	126.8	150.0	150.0	160.4	168.5
Titanium dioxide	100.0	117.4	152.4	170.9	178.0	178.1
Zinc oxide	130.1	235.4	262.4	260.7	253.2	237.0
Chrome yellow	--	--	--	108.5	117.4	124.5
Paint solvents	--	--	--	101.9	105.5	112.0
Methyl ethyl ketone	81.7	118.7	149.0	161.8	168.9	175.7
Mineral spirits	105.2	NA	175.7	185.2	201.0	237.9
Xylol (mixed xylones)	106.7	193.6	244.0	244.2	238.5	218.9
Isopropyl alcohol	--	--	--	100.2	110.6	119.6
Average Paint Materials	113.2	152.3	177.2	189.8	205.9	208.3

Source: U.S. Department of Labor, Bureau of Labor Statistics.

TABLE 5

PROFIT COMPARISON BETWEEN PAINT COMPANIES AND ALL MANUFACTURING FIRMS, 1950-1977

Year	Average Margin on Sales (percent)	
	Paint	All Manufacturing
1950	6.4	7.7
1955	6.7	6.7
1960	6.3	5.5
1965	5.6	6.4
1970	2.6	4.7
1972	3.6	5.1
1974	3.1	5.2
1975	2.4	4.4
1976	2.5	5.1
1977	2.8	5.0

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

TABLE 6

AVERAGE MANUFACTURERS' PRICES FOR PAINTS, 1967-1977
(1967=100)

Year	Index	
	Sales Paints	Industrial Finishes
1967	100.0	100.0
1968	101.0	104.9
1969	102.6	108.9
1970	104.9	116.8
1971	103.6	107.6
1972	110.1	106.8
1973	117.3	117.2
1974	118.1	148.1
1975	137.9	167.2
1976	154.8	184.3
1977	160.3	194.1

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, NJ: Charles Kline & Co., 1977).

COMPETITION AND INNOVATION

The trend toward higher prices for industrial finishes is indicative of the search for more sophisticated paint "systems," including both the coating and the method of application and cure. As previously discussed regulatory pressures have caused reformulations that are easier and safer to apply by home consumers and cause less environmental pollution.[15] In the industrial finishes area, the manufacture of powdered or high solid coatings now calls for more sophisticated technical requirements and greatly increased capital expenditures.[16]

The National Paint and Coatings Association estimated R&D for new products at 2.2 percent of sales in 1977.[17] As research in more sophisticated coatings increases, many smaller companies may not be able to afford the funds necessary to develop and produce the new formulations that will meet both regulatory standards and purchasers' needs.[18] As a result, the trends toward industry consolidation already discussed will probably continue. (It should be emphasized that the necessary innovation will involve new formulations rather than new chemicals).

Foreign trade has never been a significant portion of business in the paint industry, and amounted to $1.13 million in exports, about two percent of total sales in 1977.[19] Although the balance of trade is favorable, growth is expected to be moderate since high shipping costs relative to the cost of goods makes overseas distribution unattractive. Future import growth or product substitution by imports will be low because of environmental restrictions.[20]

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[15] Regulations include: 1970 Clean Air Act; 1972 Fresh Water Pollution Control Act Amendment; 1976 National Education and Disease Preventon Act; 1970 Occupational Safety and Health Act; 1970 Hazardous Materials Control Act.

[16] U.S. Department of Commerce, 1978 U.S. Industrial Outlook, p. 119.

[17] National Paint and Coatings Association, Operating Cost Survey.

[18] The top 34 companies accounted for 72.4 percent of sales in 1977, leaving 1,241 very small firms with average sales of only $1.13 billion per firm.

[19] U.S. Department of Commerce, U.S. Exports, FT 410, 1978.

[20] C.H. Kline & Co. forecast.

E-300

Adhesives and Sealants

ADHESIVES AND SEALANTS

DESCRIPTION

An adhesive is a bonding agent that holds similar or dissimilar substrata together. "Adhesive" is a generic term that applies to a wide variety of chemical compounds including glues, cements, and mucilage. "Glue" orginally referred to animal-derived adhesives used to bond wood together, but now refers to all classes of adhesives. Mucilage is a solution of vegetable gums generally used for bonding paper. Cements include a wide class of natural rubber, thermo-plastic resin, and synthetic elastomer bonding agents. Sealants (and caulks) are used to fill gaps or joints, and may also function as waterproofing agents.

The base material of adhesives and sealants can be mineral, natural organic, or synthetic. The industry is defined by application rather than by chemical type, and measurements of the activity of the industry have varied because of differing categorizations. The Bureau of the Census' definition includes firms engaged in the manufacture of industrial and household adhesives, sealants, and caulks for further resale; it excludes firms engaged in "the manufacture of plastics and resins. . . for protective coatings,"[1] as will this discussion. Also, the manufacture of adhesives for captive use[2] and inorganic adhesives such as Portland cement, soluble silicates, hydraulic cements, phosphate cements, and thermosetting powdered glasses will not be considered.

Natural Adhesives

Until the advent of petroleum derived adhesives, the industry was composed of animal and vegetable based products. These included hide and bone glues, protein adhesives, vegetable adhesives, coal tars, and rubber-type cements. In general, these natural products are less expensive than their synthetic counterparts, but they are also are less versatile. Table 1 shows the change in product mix between natural and synthetic products in 1967, 1972, and 1977.

Currently, the animal glues are widely used in paper packaging and in some wood furniture applications. Vegetable adhesives such as dextrin are among the lowest in cost per pound, and are used where water resistance is not important, such as with can and bottle labels. Rubber cement, sold as such, is used for rubber bonding and bonding where the ease of later removal is important, e.g., with graphic arts.

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[1] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979), p. 1.

[2] Examples are shoe or plywood manufacturers who purchase raw materials and make their own glues for use in the finished product only.

TABLE 1

U.S. SHIPMENTS OF ADHESIVES BY TYPE: 1967, 1972, 1977
(millions of dollars)

		U.S. Shipments	
Item	1967	1972	1977
Natural base adhesives			
Animal	35	31	51
Protein	16	12	23
Vegetable	27	46	43
Other	20	31	44
Subtotals:	98 (20.6%)	120 (14.4%)	161 (11.4%)
Rubber Cements	67 (14.1%)	94 (11.3%)	160 (11.3%)
Other	20	41	81
Synthetic Resins	290 (61.0%)	578 (69.4%)	1,016 (71.7%)
Grand Totals:	475	833	1,418

Source: U.S. Department of Commerce, Bureau of the Census, 1967 Census of Manufactures (Washington, D.C. Government Printing Office, 1970); 1972 Census of Manufactures (1975); 1977 Census of Manufactures (1979).

The natural and rubber adhesive segments of the adhesives industry were in existence long before the advent of synthetics and are naturally more mature in terms of products and pricing. Generally, animal and natural rubber base adhesives are pseudo-commodity products with low cost as an important selling feature.[3] They must compete against more versatile synthetic adhesives, and usually this is possible only with lower prices.

Synthetic Adhesives

The advent of synthetic products started with synthetic rubber-based cements and spread to petroleum-based glues and cements. Currently there are several major classes of synthetic cements, including epoxies, phenolics, amino resins, polyvinyls, hot melts and specialty adhesives.

Table 2 shows the growth of the major classes of synthetic adhesives between 1972 and 1977.

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[3] C. H. Kline & Co. defines pseudo-commodities as differentiated end products but, like true commodities, they are sold in relatively large volumes, are widely used, and may have the bulk of their sales concentrated in a few large customers.

TABLE 2

SALES OF SYNTHETIC ADHESIVES, 1972 and 1977

Adhesives	Sales[a] (millions of dollars and percent of total) 1972		1977	
Epoxies	48.2	(8.3%)	70.8	(7.0%)
Phenolics	53.4	(9.2%)	114.7	(11.3%)
Polyvinyls	183.9	(31.8%)	258.7	(25.5%)
Hot melts	27.6	(4.8%)	114.0	(11.2%)
Synthetic Rubbers	149.8	(25.9%)	289.9	(28.5%)
Other specialty	115.4[b]	(20.0%)	167.4	(16.5%)
TOTALS:	578.3	(100%)	1015.5	(100%)

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures, (Washington, D.C.: Government Printing Office, 1979).

[a] Overall data may be 15-20 percent too low according to C.H. Kline & Co. estimates.

[b] Estimated.

Epoxies are among the most expensive adhesives per pound and accounted for slightly more than $300 million in sales in 1978.[4] The markets for epoxies are in stable, high performance areas, and growth projections ranged from 3 to 8 percent over 1978.[5] These market areas include automobiles, appliances, protective coatings, electrical laminates and construction. Ninety percent of sales are epoxies that are made from a reaction of biphenol A with epichlorohydrin. OSHA currently has a 5 ppm (parts per million) exposure standard for epichlorohydrin, and may lower this standard because of carcinogenic concerns.[6] The long term economic effects of such an action are unclear at this time, although formulation of epoxy without the use of epichlorohydrin is more expensive.

Phenolics are the largest volume class of synthetic adhesives sold. Their primary use, about two-thirds of their volume annually, is in plywood and particle board applications; therefore, sales are tied to the construction market. Phenolics, considered pseudo-commodities, were among the first synthetic adhesives developed, and replaced animal glues in many wood applications.

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[4] Chemical and Engineering News, August 16, 1979.

[5] Ibid., p. 14.

[6] Ibid.

The polyvinyls, including polyvinyl acetate and polyvinyl chloride, have extensive uses in food packaging, furniture assembly, and general purpose household glues.[7] Because of their variety of applications, they are considered more like general purpose chemicals than like specific use chemicals, and they are commodity items. In 1977 their tonnage of sales was exceeded only by the phenolics.[8]

The hot melts, introduced in the last 15 years, are the fastest growing class of synthetic adhesives.[9] There are several types including nylon and polyolefin. Hot melts typically contain up to 40 percent ethylene-vinyl acetate copolymer in paraffin wax, and are melted to produce adhesion. This makes them unique because there is no solvent to evaporate; thus, they are becoming increasingly important in terms of lowered air pollution from evaporated solvents. Hot melts have a wide range of applications including packaging, bookbinding, shoemaking, metal bonding in cans, and furniture assembly. Thet are also used in the aerospace, transportation, and construction industries.[10]

Sealants and Caulks

The sealant industry is closely aligned with the adhesives industry. There are a wide variety of natural and synthetic sealants including bituminous asphalt, oleoresins, natural and synthetic rubbers, polymeric resins, polysulfides, and silicones.

Bituminous asphalt sealants are used to seal concrete pavement and pipes and have automotive applications as well. Oleoresins are used as putties and archítecural glazing compounds. The natural and synthetic rubbers have a wide variety of applications in building construction and windshield sealing. Polysulfide sealants have industrial applications in aircraft and fuel tanks and in expansion joints for bridges, buildings and roadways. Silicone sealants and caulks have high and low temperature applications for metal, concrete, plastic, and wood. They are used extensively in automotive and marine applications and in the aerospace industry to encapsulate electric connections.

INNOVATION

Some firms in the adhesives and sealants segment seem to engage in little new chemical entity creation. However, a large number of companies in the segment produce chemicals for manufacturers seeking adhesives with special properties. These companies do have a high rate of innovation.

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[7] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 153.

[8] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

[9] Meegan, Kline Guide.

[10] Encyclopedia of Chemical Technology (3rd ed., New York, N.Y.: John Wiley & Sons, N.Y., 1978), Vol. 1.

PRICE AND PRODUCTION TRENDS

This section presents a discussion of industry structure, price and production trends, the likely impacts of concerns over toxic substances, and the increased costs of energy and raw materials.

Because of the wide variety of applications for adhesives and sealants, the industry is relatively diverse and has a large number of medium and small size firms. In 1977 there were 750 manufacturers, only 100 of whom had sales in excess of $2 million.[11] Of these 750, however, 50 companies accounted for 68 percent of the $954 million in industry sales for 1972 (an average of approximately $13 million per firm), leaving $305 million among 700 companies.[12] The large companies usually have a multiple product line, and the smaller companies specialize in product or market areas.

Recent prices reflect the impact of higher petroleum and process costs. Table 3 shows the wholesale price indices of three major types of adhesives from 1967 through 1977. The production of many adhesives, such as hot melts, is energy intensive. This factor resulted in increased expenditures on R&D over the past several years in an effort to find less energy intensive ways of making and applying adhesives and less expensive raw materials.[13]

In addition, increased concern over the carcinogenicity of materials and solvents has prompted the search for new compounds whose intermediates are not toxic and whose solvents are not as polluting.[14] For example, formaldehyde emissions from the urea formaldehyde adhesives used in construction have come under government scrutiny. This concern has prompted a high degree of innovation. For example, in June 1979 General Electric's Plastic Division announced a one component epoxy that is set by heat, citing advantages of lack of storage problems and the elimination of vapor emissions. However, prices are 25 to 100 percent higher per pound than the industry averages for epoxies presently used.[15] "Glue sniffing" in the past has received widespread public attention, and manufacturers have looked for substitute solvents and compounds for general purpose glues.[16]

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[11] Meegan, Kline Guide, p. 134.

[12] Ibid., p. 135.

[13] Encyclopedia of Chemical Technology, p. 155.

[14] For example, the 4-4'-methylenebis (2-choloraniline) intermediate found in several varieties of phenolics, which is listed as a carcinogen by OSHA.

[15] Chemical and Engineering News, June 4, 1979, p.4.

[16] Ibid., p. 156.

TABLE 3

WHOLESALE PRICE INDICES FOR SELECTED ADHESIVES, 1967-1977

1967 = 100

Year	Animal Glues	Phenolic/ Vinyls	Rubber/ Phenolics
1967	100.0	100.0	100.0
1968	100.0	102.2	100.4
1969	104.0	107.6	102.8
1970	105.6	113.5	107.6
1971	110.5	116.7	111.3
1972	110.5	116.9	111.7
1973	128.0	119.5	111.7
1974	196.1	138.1	137.2
1975	279.0	--	174.3
1976	221.1	--	178.8
1977	163.2	--	184.9

Source: U.S. Department of Commerce, Wholesale Price Index, various years.

Production of adhesives, caulks, and sealants will parallel the consuming industries, as previously mentioned. Although growth in the past has been moderate and oriented towards traditional users, new applications in other industrial areas will be the major fields of future growth. These areas should include metalworking, aerospace, and transportation.[17]

Table 4 illustrates the growth in sales of adhesives and sealants from 1967 through 1977 with estimates for 1980 and 1985 total sales.

In summary, pressure from rising raw material and rocessing costs as well as more stringent air quality standards may force major changes in the products and manufacuring techniques for adhesives and caulks. TSCA's impact may be somewhat felt in the area of epoxy but OSHA standards may ultimately have more impact here. Thus, TSCA's eventual impact will probably be overshadowed by broader, more compelling, and more urgent concerns of pollution and rising input costs.

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[17] Meegan, Kline Guide, p. 133.

TABLE 4

U.S. SHIPMENTS OF ADHESIVES, CAULKING COMPOUNDS AND SEALANTS, 1967-1977

(millions of dollars)

	Caulking compounds and sealants	Adhesives	Total
1967	$68	$475	$543
1968	76 a/	524	600
1969	86 a/	580	666
1970	96 a/	548	644
1971	108 a/	608	716
1972	121	833	954
1973	163	989	1,152
1974	232	1,172	1,404
1975	262	1,209	1,471
1976	300	1,350	1,650
1977	355	1,425	1,750
1980 a/	--	--	2,175
1985 a/	--	--	3,125

a/ Estimate.

Sources: U.S. Department of Commerce, Bureau of the Census, 1967 Census of Manufactures and 1972 Census of Manufactures (Washington, D.C.: Government Printing Office, 1970 and 1975); and estimates by C. H. Kline & Co.

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Explosives

EXPLOSIVES

OVERVIEW

This section gives the basic chemistry of widely used explosives and a general description of their uses. It does not include government-owned contractor plants, civilian ammunition, or fireworks and pyrotechnical production. A later section discusses production, sales, and competition.

An explosive is a material that undergoes very rapid decomposition or autocombustion (auto-oxidation). There are two principal classifications for explosives:

- low explosives, which autocombust at speeds less than 400 meters/second (the speed of sound), and
- high explosives, which detonate at speeds ranging up to 8,500 meters/second.

In addition, high explosives are subdivided into categories that (a) explode when subjected to heat, impact or friction; thus they can be used as detonating agents, and (b) those that are insensitive to external forces and must be exploded using a detonating agent.[1]

Insensitive high explosives are called blasting agents. In 1856 Alfred Nobel developed the first blasting agent--dynamite, which is nitroglycerine soaked in cellulose or other inert material--and for a century it held the major market share for mining explosives. In 1955, however, ANFO, a mixture of approximately 90 percent ammonium nitrate and 10 percent fuel oil began to replace dynamite because it was much less sensitive to shock, less expensive, and could be mixed on-site to yield greater explosive power.[2] Other blasting agents used today include Tri-nitrotoluene (TNT), nitroglycerine, ammonium picrate and cyclotrimethylenedinitramine (cyclonite). Initial detonating agents include lead azide, mercury fulminate, and diazodintrophenol. These agents are produced in smaller quantities than blasting or low explosive agents due to their more hazardous nature.

Explosives are also categorized by function:

- Propellants--low explosives that generate large volumes of gases and are used for rockets, missiles, flares, shearing bolts, driving turbines, and signaling. They can be liquid or solid and can be individual compounds or mixtures of several compounds.

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[1] Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 146.

[2] Stanford Research Institute, Chemical Handbook, 1978.

- Permissible explosives--approved for use in coal mines because of their safety when used in a coal dust atmosphere; usually modified nitroglycerine.
- Military explosives--those used in shells and bombs; TNT and ammonium picrate are widely used.
- Ammunition primers--formerly potassium nitrate, now lead styphirate or tetracene.[3]
- Blasting agents--ammonium nitrate and fuel oil mixtures or slurries of TNT, sulfur aluminium and ammonium nitrate.

None of the high or low explosives are toxic in use, although many are extremely dangerous simply by the nature of their function and sensitivity. With the exception of the ANFO mixtures, the actual chemicals in explosives are tightly packaged for use and have little or no physical contact with users. Production is made under carefully controlled and often isolated conditions, where automated and remote control mixing, handling, and packaging equipment removes much of the inherent physical danger from inadvertent explosion.[4]

PRODUCTION, SALES AND COMPETITION

As might be expected, there are no substitutes for explosives other than cheaper, more powerful, and safer-to-handle explosives, and there is a very restricted market for the majority of products. These markets, mining and heavy construction, have exhibited a relatively slow and stable growth rate in the past 15 years.[5] As a result of this stability, volume growth of explosive sales has averaged just over 5.8 percent yearly between 1967 and 1976. Table 1 illustrates the slow growth in production for the major categories of industrial explosives.

Although it shipped $450 million worth of products in 1977, the industry is small in comparison to most other chemical segments. Table 2 compares the sales of the industrial explosives industry with several other representative segments.

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[3] Meegan, Kline Guide, p. 148.

[4] Illustrated Science and Invention Encyclopedia (New York, N.Y.: H.S. Stuttman Co., 1977), Vol. 7, 1977.

[5] U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, various years).

TABLE 1

U.S. CONSUMPTION OF INDUSTRIAL EXPLOSIVES BY TYPE: 1967, 1972, 1977

(millions of pounds)

Blasting Agents	1967	1972	1976
Cylindrical agents	66	266	350
Water gels	167	226 a/	339 a/
Other	1,288	1,862	2,393
Subtotal:	1,521	2,354	3,082
Fixed High Explosives			
Permissible	69	46	45
Other	305	270	202
Subtotal:	374	316	247
Grand Total:	1,895	2,670	3,329

a/ Classification changed from 1967, now excludes some explosives formerly in that category which are not included in "Other".

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook (Washington, D.C.: Government Printing Office, various years), and U.S. Department of Interior, Bureau of Mines, Mineral Industry Surveys, 1967, 1972, 1976.

TABLE 2

COMPARISON OF INDUSTRIAL EXPLOSIVES SALES WITH OTHER CHEMICAL SEGMENTS: 1977

Segment	Sales (millions of dollars)
Industrial explosives	450
Petrochemicals	21,000
Inorganics	10,350
Plastics	11,615
Pesticides	2,850
Catalytic preparations	365
Organic dyes and pigments	1,135

Source: Mary K. Meegan, ed., Kline Guide to the Chemical Industry (3rd ed., Fairfield, New Jersey: Charles Kline & Co., 1977), p. 4.

The relatively mature nature of the market, coupled with the pseudo-commodity nature of the products has acted to concentrate the producers.[6] The three largest, DuPont ($110 million), Hercules ($90 million), and Atlas Powder ($87 million), dominated the industry in 1977 with 66 percent of total sales. The top eight companies comprised 83 percent of U.S. shipments in 1977.[7]

As previously mentioned, the markets for industrial explosives are both concentrated and limited. Table 3 illustrates the relative consumption of explosives by user industry for 1970, 1974, and 1976.

TABLE 3

INDUSTRIES CONSUMING EXPLOSIVES: 1970, 1974, 1976

(percent of total)

	1970	1974	1976
Coal mining	44	49	54
Metal mining	20	17	15
Quarrying	19	20	15
Construction	17	13	16
Totals:	100	100	100

Source: Minerals Yearbook, 1970, 1974, 1976.

There have been rapid increases in the prices of explosives in the last five years. Bureau of the Census data show annual price increases of 18.3 percent for ammonium nitrate slurry explosives and 15.0 percent for ANFO explosives between 1972 and 1977. These two categories made up 31.6 percent of total sales in 1977.[8] However, raw material prices of ammonium nitrate, the main constituent in these explosives, increased 20.7 percent per year during the same time period.[9] This margin squeeze has caused American

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[6] C.H. Kline & Co. defines "pseudo-commodity" chemicals as those which are differentiated end products but are formulated in large volumes and often have the bulk of their sales concentrated in a few large customers.

[7] Meegan, Kline Guide, p. 149.

[8] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

[9] Ibid.

Cyanamid, once a major explosives producer, to leave the industry. In fact, the squeeze may continue to further concentrate the industry.[10]

We believe that no urgency to develop new explosives currently exists since there is little risk of substitution by other products and sales growth is expected to remain very slow. Rather than seek new ones, R&D seems to have concentrated on improvements and refinements to existing products to make them safer to handle and use. Efforts to hold down or reduce processing costs are somewhat stymied by the batch processing nature of manufacture[11] and the elaborate safety precautions that must be taken to avoid premature detonation. As a result of these restrictions, we feel that TSCA should have little or no effect on this relatively isolated and mature industry.

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[10] Meegan, Kline Guide, p. 149.

[11] Illustrated Science Invention and Encyclopedia.

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Printing Ink

PRINTING INK

The printing industry produces mixtures of pigments and binders made from inorganic and organic pigments and organic dyes. The average firm employs 13 people and had slightly over $2.1 million in sales in 1977.1/

Most printing inks are colloidal mixtures, and chemical reactions are not employed to make these items. Thus, aspects of this segment will not be affected by TSCA and will not be discussed. Although the printing ink industry has long had a very low degree of innovation, recently a new process and new products have recently been developed. Previously, ink dried on the paper as a solvent evaporated. Now ink is being "cured" with infrared heat. Unlike most firms in the segment, the firms developing the new technology and products are not simply blending existing ingredients; they are developing new chemicals and will therefore be affected by TSCA.

1/U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

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Toilet Preparations

TOILET PREPARATIONS

Major categories in the toilet preparations industry include:

- Shaving preparations;
- Perfumes;
- Hair preparations;
- Dentifrices;
- Creams, lotions;
- Lip, eye cosmetics;
- Deodorants;
- Manicuring preparations;
- Powders, and
- Bath salts, oils, and bubble baths.

Section 3(B)(vi) of the Toxic Substances Control Act precludes regulation by the Act of any cosmetic as defined and controlled by the Food, Drug and Cosmetic Act of 1938. Section 201 of the Act defines cosmetics as:

> "(1) articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance, and (2) articles intended for use as a component of any such articles; except that such term shall not include soap."

Therefore, SIC 2844 will not be affected by TSCA and will not be discussed.

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Carbon Black

CARBON BLACK

Carbon black serves as a relatively cheap reinforcing agent for rubber. It is a single element, carbon. The most common production process, which accounted for 92 percent of production in 1976,[1] is furnace combustion. Virtually all carbon black is synthesized from "carbon black oil," a liquid petroleum refinery fraction which uses heat, does not use catalysts, and produces no intermediates.

Because there is no chemical substitute for the element, there will be no "new products". Therefore, this industry will not be discussed.

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[1] U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979).

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Salts, Essential Oils, and Chemical Preparations, NEC

SALT, ESSENTIAL OILS AND CHEMICAL PREPARATIONS, NEC

SALT

This SIC includes evaporated salts from seawater and brine. Because there is no chemical conversion, this industry will not be discussed here.

ESSENTIAL OILS

The SIC Essential Oils includes flavorants derived from natural sources such as peppermint, lemon, orange, spearmint. Section 2(B)(vi) of the Toxic Substances Control Act precludes any food additive, including essential oils, that are controlled by the Food, Drug and Cosmetic Act of 1938 and amendments, from coming under the provisions of TSCA. Therefore this industry will not be addressed.

CHEMICAL PREPARATIONS, NOT ELSEWHERE CLASSIFIED

This SIC includes a widely divergent set of chemical products. It cannot be easily classified by size, chemistry, market or producers. The approximate volume for this diverse group was over \$2.3 billion in 1977.[1] Table 1 shows the major categories, the number of firms in each category with over \$100,000 in shipments, the average sales per firm, and the total sales for each category.

TABLE 1

MAJOR CATEGORIES OF CHEMICAL PREPARATIONS NEC, TOTAL SALES, FIRMS, AND AVERAGE SALES OF FIRMS IN EACH CATEGORY, 1977

Category	Total Category Sales ($ millions)	Number of Firms with shipments greater than $100,000	Average Sales Per Firm ($ millions)
Automotive Antifreezes	299.8	34	8.82
Plating Compounds	254.1	21	12.10
Boiler Compounds	218.3	38	5.74
Water Softening Compounds	199.8	27	7.40
Metal Treating Compounds	169.7	3	56.57
Foundry Supplies	153.5	24	6.40
Drilling Heads	124.6	15	8.31
Sizes	103.4	10	10.34

Source: U.S. Department of Commerce, Bureau of Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979);and ICF estimates.

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[1] U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufactures (Washington, D.C.: Government Printing Office, 1979); and ICF estimates.

There are no publicly available data that identify the actual relative standing by sales of firms, or that identify the total number of producers or producers by name in any of these categories. With the exception of the metal treating compound category, which appears to be highly concentrated, little else can be surmised about the industry structure without going directly to firms themselves for information.

Antifreeze compounds are ethylene and propylene gycols, which are made by several methods. One such method includes the heating of ethylene or propylene chlorohydrine in a bicarbonate solution, and the oxidation of ethylene or propylene with air , followed by hydration with weak acid. Processing is done in large quantities and is usually continuous.[2] Used since before World War II, glycol antifreezes form a commodity product whose growth closely follows that of the auto industry. No product substitution is foreseen due to the low cost and excellent properties of glycols.

Plating compounds are ionic solutions of metals, either acidic or basic and are plated onto a substrate by electrodeposition. The most common metal is chrome, followed by copper. Other metals include silver, gold, tin, nickel, barium, platinum, selenium, and palladium. No data are available for amounts of each metal used in any year.

The chemistry of each plating compound may differ depending on the primary metal being plated and the substrate. Because of the nonsubstitutability of metals and the necessity for a particular solution for any given plating process, the probability is small that changes will occur in plating solution products.

Boiler compounds are used to scavenge oxygen and chlorine from feed water as well as to inhibit the deposition of magnesium and calcium scale on tube walls. These chemicals are added to the feed water at a boiler installation.

These chemicals are of two major varieties: acid cleaners, used to remove scale and particle buildup from boiler tubes; and water treatment compounds, used to scavenge free oxygen, chloride, and metallic ions from the feed water. Acid cleaners are simply mixtures of acids and surfactants, whose manufacture is discussed in separate chemical profiles. Metal scavenging compounds are generally sodium polyphosphates or other complexing compounds. These inorganic compounds cannot be substituted by other more effective additives because they are suitable for the reaction sought. Therefore, it is extremely unlikely that innovation will change the nature of these compounds; thus, we believe that TSCA will have no impact on them.

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[2] Gessner G. Hawley, ed., The Condensed Chemical Dictionary (8th ed., New York: Van Nostrand Reinhold Company, 1971).

Water softening compounds are used industrially and in private homes to remove calcium and magnesium ions that "harden" water. Typically, an exchange medium like zeolite, a natural hydrated silicate of aluminum and sodium, ionically exchanges the calcium and magnesium ions in hard water for sodium within the zeolite. Once the resin is saturated with these ions, it is flushed with a strong salt solution to reverse the reaction and regenerate the exchange medium.

Artificial exchange resins are made in a variety of forms but are generally cross-linked polymers (organic resins of sulfonic, carboxylic, phenol, or amino groups) in small bead form.[3] They are packed in towers or tanks that water passes through and are regenerated in the same fashion as the natural zeolites. Dow and DuPont are major suppliers, but no indivdual public data are available on production for either company. The water softening industry has been in existence more than 40 years, and generally the products are sold not purely on a basis of price for the chemicals but for a service package that includes installation and periodic regeneration.

Metal treating includes the use of acids, gases, and detergents. The production of these items are discussed separately in different chemical segment profiles.

Sizes include dextrin and resins. Dextrin is made by acid hydrolysis of starch and has been in use for many years. Its low cost and wide acceptance make it unlikely that product substitution will occur. Resin is a natural product and will not be discussed here. The use of sizes is closely tied to the textile industry.

Foundry supplies include different oils. The production of these items is discussed in a separate chemical profile.

Drilling muds are basically clay and water, occasionally with cellophane flakes added. Because these muds are mixtures of naturally occurring products (except cellophane which is discussed in a different chemical profile) they will not be discussed here.

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[3] Ibid., p.474.